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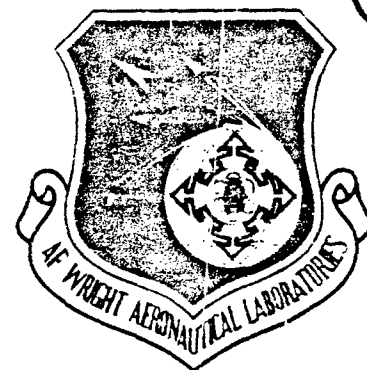
ICAM INTEGRATED PLANNING SYSTEM (IPS)

Volume I — Project Overview

General Electric Company
Production Resources Consulting
One River Road
Schenectady, New York 12345

November 1984

Final Report for Period 26 September 1980 — 31 May 1984



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ICAM Project Manager

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For The Commander:

N. G. Tupper
NATHAN G. TUPPER
Chief
Computer Integrated Mfg Branch

28 May 85
Date

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FIELD	GROUP	SUB. GR.										
03	03	Celestial Mechanics										
13	08	Ind. Processes										
19. ABSTRACT (Continue on reverse if necessary and identify by block number) <p>This final Technical Report, Volume I, describes a Production Planning and Control System (PP&CS) that was developed utilizing the Integrated Computer-Aided Manufacturing (ICAM) life cycle. An extensive study of the Manufacturing Planning and Control activities of aerospace manufacturing led to the conclusion that substantial benefit could be achieved by focusing on the control and scheduling activities from the Master Schedule through Shop Floor Control. PP&CS is a closed loop control system which operates from the Master Schedule and consists of the following major activities:</p> <ul style="list-style-type: none">Material Requirements Planning (MRP),Sequence Loading and Balancing,Release Production Requirements,Record and Provide Production Information,Resultant Processing. <p>MRP Systems are presently being marketed and thus were not designed as part of this project. The remaining functions were designed and Sequence Loading & Balancing and Record & Provide Production Information were coded for a demonstration.</p>												
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Productivity benefits are expected by use of PP&CS in reduced direct labor, indirect labor and cycle time while resource utilization will be improved through better planning and scheduling.

The report first discusses the understanding of the problem developed by working with aerospace contractors in three major planning and control activities: Make and Administer Schedules and Budgets, Plan Production, and Plan for Manufacture. This is followed by a discussion of the Preliminary and detailed Design Activities followed by a description of the Construct, Integrate, and Test activities.

The Final Report consists of seven volumes as follows:

- Volume I: Project Overview
- Volume II: Product Specification - Factory Loading
- Volume III: Product Specification - Record and Provide Production Information
- Volume IV: Product Specification - Release Production Requirements
- Volume V: Product Specification - Resultant Processing
- Volume VI: User's Manual
- Volume VII: Product Specification - Data Base

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PREFACE

This final report covers the work performed under Air Force Contract F33615-80-C-5141. This contract is sponsored by the Materials Laboratory, Air Force Systems Command, Wright-Patterson Air Force Base, Ohio. It was administered under the technical direction of Mr. Nathan Tupper, ICAM Program Manager, Manufacturing Technology Division, through the Project Manager, Lieut. Douglas Eubanks. The General Electric project manager was Mr. Ralph Navarretta of Production Management & Systems Consulting.

The subcontractors and their contributing activities were:

<u>Subcontractors</u>	<u>Role</u>
Northrop	Prepare model for factory view
General Dynamics	Prepare model for factory view
Rockwell International	Prepare model for factory view
Illinois Institute of Technology Research Institute (IITRI)	Develop viewpoint of small and medium- size aerospace manufacturers and to build shallow factory models
SofTech	Provide consulting to the coalition on IDEF ₀ (function) modeling
D. Appleton Co.	Provide consulting to the coalition on IDEF ₁ (data) modeling
Pritsker and Associates	Provide consulting to the coalition on IDEF ₂ (dynamic) modeling and act as a simulation advisor
Systems & Applied Sciences	Review requirements and preliminary designs
General Electric Corporate Research and Development	Provide simulation tasks
Control Data Corporation	Provide information systems requirements
Virginia Polytechnic Institute (VPI)	Provide state-of-the-art review and technology survey

NOTE: Note that the number and date in the upper right corner of each page of this document indicate that the volume has been prepared according to the ICAM Configuration Management (CM) Life Cycle Documentation requirements for a Configuration Item (CI).

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Section 1

INTRODUCTION

1.1 OBJECTIVES

The objectives of this project were to establish, by the ICAM System Methodology, the requirements definition, preliminary design, and detailed design of an Integrated Planning System (IPS) to support the hierarchy of aerospace manufacturing, and to provide a demonstration of a short-term product by building and demonstrating an appropriately scoped IPS supporting the Integrated Sheet Metal Center (ISMC).

The importance of this project is emphasized by the fact that current deficiencies in higher-level planning systems for aerospace production are limiting the implementation of leading edge technology. The deficiencies prevent the optimization of:

- material planning
- equipment and tool requirements planning
- capacity planning
- process plans and alternatives
- schedules
- shop floor loading
- order release systems

This planning system is responsible for providing the plans and schedules needed to convert engineering designs into manufacturing requirements, that will support product delivery to the customers.

If an integrated computer-aided manufacturing system is to be successfully implemented in the aerospace manufacturing environment, an evolutionary technical baseline for planning and control through an IPS is imperative.

The early work on the project encompassed detailed study of the present environment of the static and dynamic planning activities in aerospace manufacturing. This environment is represented by three nodes as defined by the ICAM composite view of Aerospace Manufacturing: Plan for Manufacture, make and Administer Budget and Schedules, and Plan Production. This detailed study, which developed prioritized needs for improvements, led to a focus in later phases of the project on the dynamic planning activities, primarily those associated with planning and control activities from Master Schedule Generation through Shop Floor Release. As the project continued in preliminary and detailed design, the planning and control activities were designed and further examined.

Study has shown that Master Schedule Generation, Material Requirements Planning (MRP), and Capacity Requirements Planning (CRP) generally have been pursued by several vendors who are aggressively starting to enhance current offerings to accommodate the needs of aerospace manufacturing. It therefore became apparent that the contract resources should

be devoted to those areas that are not specifically being addressed and are considered to be of significant value to aerospace manufacturing.

These Planning and Control areas are:

- Factory Loading
- Release Production Requirements
- Record and Provide Production Information
- Perform Resultant Processing

1.2 PRINCIPAL TASKS

The principal project tasks were as follows:

A. Phase I -- Understand the Problem

Phase I, Understand the Problem, consisted of a Needs Analysis of the areas under investigation and then an assessment of the potential benefits to be derived from addressing these areas. Since the scope of the project was broad, involving the study of more than 100 activities, the Needs Analysis was extremely important in focusing the effort for the remainder of the project. The areas of effort were then prioritized according to the potential benefits which could be derived if the needs of these functional areas were satisfied.

The Requirements Analysis was concerned with establishing the requirements for an eventual system and developing a prioritized list of improvements that could address the principal benefits to be realized. To do this, data were collected on existing factories to characterize their current operation. A "factory view" was then established for each of the factory studies using methodology consisting of three models to represent three different views of a system. IDEF₀ was a functional model emphasizing the activities performed, IDEF₁ was the information model emphasizing the relationships of data in the system, and IDEF₂ was the dynamic model representing the operation of the system with the functions and the data.

Three principal aerospace subcontractors (Rockwell International, General Dynamics, and Northrop) each developed a factory view of their own factories, while Illinois Institute of Technology Research Institute (ITTRI) developed a factory view of a small and a medium-sized subcontractor. These factory views, consisting of function (IDEF₀) and information (IDEF₁) models, were then combined to establish a "composite view," which contained the functions required by all of the factory views. Finally, based on the composite view, "improvement concepts" were formulated as potential ways in which the system could be improved and the potential benefits realized.

With the composite view and the improvement concepts being considered, a survey was made of the state of the art to determine what already existed that was applicable to the system and needed to address the improvement concepts. A comparison of the State-of-the-Art Survey results and the improvement concepts identified unavailable technology ("technology voids") that needed to be addressed to satisfy the requirements of the system.

B. Phase II -- Formulate and Justify Solution

Formulate and Justify Solution was composed of two principal activities: preliminary design and detailed design. In the preliminary design, alternate solutions were formulated

and evaluated using such tools as simulation, consensus, analysis, and discussion by review teams. Once a preliminary design was established, the detailed design activities developed Configuration Items (CI's) which were the modules of the PP&CS system.

C. Phase III - Construct, Integrate, and Test Subsystem

After a detailed design was established, the third phase, Construct, Integrate, and Test Subsystem, involved implementation of an IPS prototype system.

The prototype system consists of a Factory Loading module that includes the following:

- Prepare MRP Input
- Long-Term Loading (LTL)
- Long-Term Balancing (LTB)
- Short-Term Loading (STL)
- Short-Term Balancing (STB)
- Simulation Capability
- Process Planning Input
- Define Factory Capacity
- Display Capacity
- Display Load vs Capacity
- Display Detailed Capacity vs Load Profile
- Display Load/Balancing Results
- Display Detail Load Schedule

Software was also implemented to provide the user with the following capabilities:

- Define Factory Levels
- Define Factory Resource
- Display Factory Hierarchy
- Define Machine Type
- Delete Factory Resource
- Delete Machine Type
- Maintain Shop Calendar Parameters
- Maintain Shop Calendar
- Display Shop Calendar
- Define Move Times
- Adjust Load Parameters

The software was implemented on a VAX 11/780 using a VAX 11 DBMS, DI3000 Graphics System and consists of a batch and on-line capability to perform Factory Loading and supporting transactions.

Section 2

EXECUTIVE SUMMARY

This Executive Summary provides an overview of the technical work and accomplishments of Project Priority 5501. The Executive Summary is followed by a detailed discussion (Section 3) of the project accomplishments, problems, and solutions to problems.

2.1 INTRODUCTION

The ultimate goal of an Integrated Planning and Control System is to incorporate the planning and control activities from Master Schedule Generation all the way through the manufacturing hierarchy to the shop floor control activities.

Some of these activities are presently incorporated in Material Requirements Planning (MRP) functions and have been used in a number of companies. The shop floor control activities have been addressed in the Material Control Material Management (MCMM) work under ICAM projects 6101 and 6103.

Manufacturing Control-Material Management (MC-MM) is a computer-based information system. When it is given work requirements, production instructions, and schedule information, it can be used to control the execution of work and to collect information relevant to the performance of that work.

MC-MM is a hierarchical control system designed to assist production, material handling, and stock area supervisors in optimally applying the critical resources of people, equipment, tools, and material, and to assist direct labor personnel in the performance of their work. The same functions which are applied at the first-level supervisor's level or station are also applied at the cell and center level. Each of these various levels of control must plan, load, and dispatch work and must collect feedback to analyze performance of that work. This feedback of performance along with historical data is used by PP&CS to improve planning and control information.

The Requirements Analysis work, particularly the Needs Analysis, indicated that, at a minimum, use of State-of-the-Art functionality was required in:

- Master Schedule Input
- Material Requirements Planning
- Capacity Requirements Planning
- Release of "Make" Requirements to Factory

However, it was also clear that this functionality alone would not satisfy the needs and that the control system must, in addition, provide organized feedback (resultant processing) to all of the above major activities. This feedback provides a means to base input assumptions such as span time, resource performance and lot quantity rules based on the current factory situation and its history. These rules are currently developed mainly by experience and policies.

The resultant processing is also expected to contribute to improvements in current MRP systems. Resultant processing will provide accurate and timely information relative to resource performance, work-in-process, and inventory status. This is expected to significantly improve the accuracy of the aforementioned functions. Ultimately, this information can be utilized by the Plan for Manufacturing and Plan Production functions.

The key to effective utilization and development of resultant processing is the availability of this timely and accurate resource performance information from the MCMM system at all levels of the control hierarchy.

Finally, it was necessary to integrate the process planning activities with the planning and control functions. The process planning information was used to develop the capacity requirements planning (CRP) profile of shop resources. This integration consisted of the communication of process planning information from the Plan Production activity and the organization and integration of this information so that production requirements can be released to the factory through the Release Production Requirements function.

A comparison of PP&CS capacity requirements planning was compared to commercially available CRP systems. PP&CS was found to be more advanced according to APICS definition due to the fact that PP&CS loaded at a lower level of resource, thus providing an improved measure of accuracy.

2.1.1 Overview of PP&CS

Thus, at the Production Planning and Control (PP&CS) level, the anticipated structure of the integrated planning and control hierarchy illustrated in Figure 2-1 includes:

- Master Schedule Input
- Material Requirements Planning
- Sequence Loading & Balancing
- Integration of Process Planning
- Release of "Make" Requirements
- Record & Provide Production Information
- Factory Feedback
- Resultant Processing

These activities produce production requirements for the factory hierarchical control system.

The benefits expected to be achieved from a Production Planning and Control System are:

- Reduced Direct and Indirect Labor
 - Through better application of labor
- Reduced Cycle Times
 - By identifying and resolving bottle necks
- Reduced Inventory
 - By better control of job starts on the shop floor along with tracking of completions.

- Improved resource utilization
 - By providing a balanced load according to a prioritized schedule
- Increased factory Throughput
 - By scheduling and loading the factory based on historical and current data which will allow opportunity to reduce cycles.
- Ability to analyze performance to plan
 - By providing a closed loop feedback system between PP&CS and the shop floor
- Reduced management overhead
 - By identifying problems early to decrease expediting
 - Exception reporting vs. mass print outs

The modules of PP&CS which were constructed and implemented for demonstration under Project Priority 5501 are:

- Sequence Loading and Balancing
- Release Production Requirements
- Record and Provide Information
- Resultant Processing

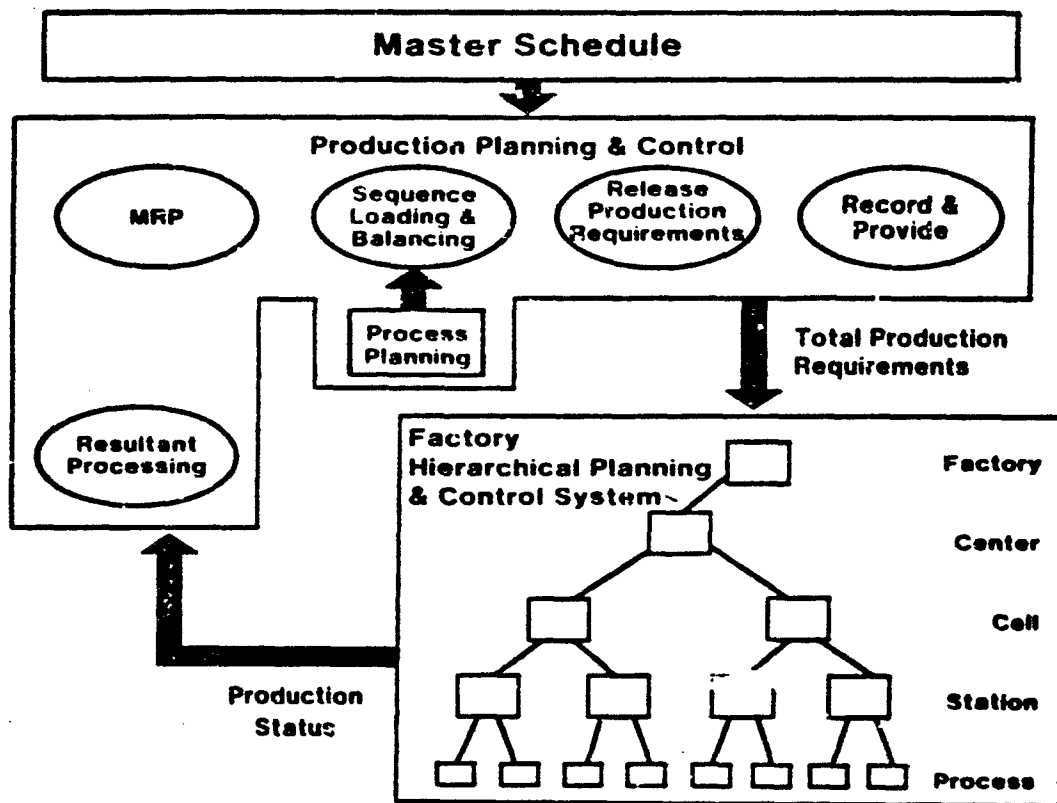


Figure 2-1. Production Planning and Control Concept

The modules such as master scheduling, material requirements planning (MRP), process planning, and the shop floor control system can be implemented via existing commercially available systems.

Following is a brief description of these activities:

A. Master Schedule Input

Master scheduling is basically a work planning assignment. It is the task of committing factory production resources — manpower, machines, and materials — to filling actual or anticipated customer orders. In brief, the question that must be answered is: "How can available factory capacity be best utilized to make the required number and variety of shippable end items?" The output from master scheduling is customer products or major components with associated quantities and completion dates. Inputs come from all facets of the business: Marketing, Engineering, Manufacturing Engineering, and Purchasing. This activity transforms management's operating strategies for each function of the business into unified operating goals.

During master scheduling, specific quantities and dates are assigned that will trigger the entire production process. The Master Schedule authorizes both factory and office to spend money and sets production performance standards throughout the organization. Changes, alterations, failures and even successes should be carefully analyzed. The master schedule is manufacturing's common goal with the other functional operations within the business.

The PP&CS prototype utilizes schedule input for shippable end items and quantities from an existing higher-level system.

B. Material Requirements Planning

Material Requirements Planning is the process of converting end items specified on the master schedule into lower-level purchased and manufactured subassemblies and components. These requirements are netted against the inventory position to produce the net requirements to be purchased or placed on the factory.

The process is accomplished through a bill of material level-by-level explosion, which utilizes the manufacturing indentured parts lists. Information is contained within the manufacturing indentured parts lists to indicate the applicability of specific subassemblies and components to the product being dealt with. Each component at each level is set back, according to predetermined span times, to produce estimated availability requirement dates for the dependent lower-level subassemblies and components. The net requirements are summarized according to predetermined lot sizing policies. The results are firm orders to be placed on purchasing or the factory (production requirements). The production requirements are subjected to broad parameters of factory capabilities to determine the probability of being able to meet the specified schedule.

Records are kept of the gross requirements generated. They are identified (or pegged) to the next higher assembly or end product usage by next assembly part number and order number. The requirements records are used for supporting subsystems to allocate available inventory and produce lot sized orders on the factory.

An important advantage of the Material Requirements Planning system is the ability to track products. This tracking process determines when and where in the bill of materials changes should be incorporated into the product.

The PP&CS project uses an existing MRP system in its prototype implementation.

C. Factory Loading and Balancing

After the production requirements are created, validation of the probability of achieving the manufacture of those requirements within very broad parameters of factory capabilities is performed. Forward or backward loading on the factory is performed within the defined limits of available capacity. The production requirements are compared to the production instructions (process routing) to explode labor. Two types of loading and balancing are available. The first type is for an extended horizon (to be selected by the user). This function analyzes and loads the factory at the summary level. The load profile segment selected is of a duration long enough to identify capacity problems in a range of capacity versus load over time to attempt to solve the capacity problem through leveling of the load.

Assuming a successful summary load, a shorter horizon may be selected for detail operation loading at the process level. This is accomplished in a similar manner. Summarized analysis is performed to detect the points at which production rate changes impact capacity availability. Adjustments are made to slack time, flow time and priorities. Reloading is accomplished to develop minimum capacity requirements to achieve the load. All conditions, assumptions and unresolved problems are displayed.

The production requirements are used to plan the required capacity to achieve the load placed on the factory. Production instructions (process routings), capacity identification and availability are obtained through external interfacing systems. Span times, alternate processes, parallel processing, experience, capacity limitations and resource effectiveness are considered in establishing the planned load.

The developed load is the anticipated activity expressed in hours for a machine, department or facility. The developed load is normally constructed by multiplying the lot quantities to be built by the run time per piece and then adding the setup time for the lot.

The total work load, composed of released and unreleased load, is segregated into time periods to create a capacity versus load profile to illustrate both underload and overload situations. Once the current load situation is known, the option is available to forward or backward load and develop alternative strategies so that the best solution can be chosen considering the information currently available. The developed alternatives such as redeployment of resources, additional shifts, additional facilities, etc. are evaluated taking into account management directives, schedule restrictions and resource restrictions to arrive at the best alternatives for the particular problem.

Once a particular solution has been reached, a "plan request" can be generated to initiate the plan of action that has been chosen. The plan of action may simply be a matter of balancing the load within the schedule constraints that exist, increasing capacity to meet schedule demands, or rescheduling due to the constraints of the machine, department or facility in question.

The actual time horizons of the planned load vary depending on such factors as the characteristics of the material flow, the criticality of the manufacturing processes employed, and the rate at which resource assignments can be changed.

The PP&CS system is designed to access a system like Material Control Material Management (MCM) directly to obtain status of current load and completions.

D. Release of "Make" Requirements to Factory

Once the load has been developed for a particular item to be manufactured, that information, together with the process plan and required schedules, is released to the factory. At this

point, total load, previously released and new, has been taken into consideration. Material is either available or scheduled to meet required due dates and capacity has been developed to meet necessary manufacturing requirements. As additional load is required, the information released to the factory is updated so that the total current load is always available.

E. Integration of Process Planning

Process planning for parts and assemblies must be carried out to specify, in careful detail, the processes required and their sequence. These processes and sequence are developed to achieve minimum cost and to meet the exacting requirements of the product design specifications. The application of resources to accomplish the making of parts is complex. The complexity is due to different sizes and shapes of parts, quality of finish required, accuracy demands, and differences in output rate required. The information contained on the process master file is used as input to the sequence loading and balancing module, which constructs load hour profiles versus hours of capacity for factory resources.

The primary process planning information required to support the PP&CS Factory Loading function is as follows:

- Resource ID
- Part number
- Operation sequence number
- Setup hours
- Standard hours
- Tooling
- Material

F. Record and Provide Production Information

This function is primarily responsible for maintaining factory environment information and is also intended to maintain both planned and actual performance information. Factory environment information, e.g., machines, machine types, shop calendar information, factory organization, etc. is obtained from the organization responsible for the factory configuration. Planned information is obtained through the planning functions. Actual production information is obtained from resultant processing.

All information is validated for correct format and content. If valid, the information is stored and retrieved upon request. Experience information is reported about scrap and shrinkage, span times, yield and historical performance. Production requirements information is provided and status information is reported.

The feedback from the factory is processed, validated and stored. Performance information and recommendations are developed and fed to the factory and to the higher-level planning and scheduling functions.

G. Resultant Processing

Resultant processing comprises the analysis, conditioning, storing and use of feedback information obtained on a timely basis through the control hierarchy. It is used to predict future performance based on trends and observations obtained from prior experience.

The information to be used and analyzed, includes standard hours from process plans, planned hours from production requirements, queue size/time relationships and liquidated

hours from the factory feedback system, yield experience from scrap analysis, and present load status from the factory control system.

The information is analyzed for inconsistencies and extremes. Data within predefined limits are maintained as history. The new information is compared to historical performance. Any new trends detected will be used in the development of more realistic production requirement schedules. Predictions are made about potential progress in achieving current load based on prior performance.

2.1.2 Production Planning and Control (PP&CS) Users

The PP&CS user types are as follows:

Manufacturing Analysts

- Database Administrator
- System Analyst

Manufacturing User

- Shop Floor Control
- Manufacturing Planner
- Production Planner
- Resource Planner
- Tool Planners
- Production Schedulers

Management User

- Shop Management
- Inventory Managers
- Strategic Planners
- Company Management

2.1.3 Summary

The above discussion of PP&CS functional characteristics are expected to perform long range planning in a batch mode and dynamic and short range planning tasks on-line, using exception-type parameters and reporting.

2.2 TECHNICAL WORK AND ACCOMPLISHMENTS

The following is a synopsis of technical work accomplishment during the life of Project Priority 5501.

2.2.1 Contribution of IPS Subcontractors

Due to the large scope and size of Phase I, Understand the Problem, it was decided to apportion specific tasks to aerospace companies and to support those efforts with consultants to ensure consistency in methodology for functional and information modeling of the particular tasks. The subcontractors and their contributing activities are referenced in the Preface of this report.

2.2.2 Development of Master Plan and Schedule

A master plan and schedule was developed to define the project objectives, tasks, subtasks, schedules, budgets, materials and method, facilities, personnel and deliverables required. A Systems Environment Document (SED) was prepared to provide guidance to the IPS coalition team before the modeling activity commenced.

2.2.3 Data Collection Experiment

A data collection experiment to evaluate methodology proposed by the Air Force was conducted using subcontractor and General Electric personnel. This process used a coding system for all inputs and outputs during the data collection process. The objective was to sort by code to identify like attributes and entities that would be helpful in preparation of a system design. Results of this experiment were inconclusive.

2.2.4 Needs Analysis Identification

A Needs Analysis was performed by each of the aerospace subcontractors and General Electric for the following major subtasks of Phase I:

Task 1 Manufacturing Planning Subtask (MPS) — Performed by Rockwell International

Task 2 Process Planning Subtask (PPS) — Performed by General Dynamics

Task 3 Plan for Manufacturing Subtask (PMS) — Performed by Northrop Corporation

A Needs Analysis Document (NAD) was developed as a result of this effort.

2.2.5 "As-Is" Factory and Dynamic Models

Factory models were developed using IDEF₀ methodology for each of the major subtasks of Phase I. In addition, dynamic models were constructed of selected areas of the "As-Is" factory function models to provide dynamics data through simulation for use in constructing improvement concepts.

2.2.6 "As-Is" Composite Factory Models

Each subcontractor that had primary responsibility for the function model of a subtask in Phase I prepared a shallow model of the other subtasks on Phase I for its factory. Through analysis and consensus, composite factory models were constructed for each subtask in Phase I. The methodology was supported by modeling consultants during the "As-Is" composite factory modeling process.

2.2.7 "As-Is" Information Models

Information models were constructed for each subtask in Phase I by the responsible task leader. The models consisted of five phases of detail, as follows:

- Phase Zero — Writeup of the "Strategic Objective"
- Phase One — Definitions of Entity Classes
- Phase Two — Development of Entity Class Diagrams
- Phase Three — Define Key Attribute Classes
 - Develop Attribute Diagrams
 - Prepare Attribute Class Migration Index

- Phase Four — Define Non-Key Attribute Classes
— Prepare Function View Diagrams
— Prepare Complete Model

2.2.8 Development of Improvement Concepts

Improvement Concepts were developed as a result of prioritizing the Needs Analysis to determine a concept for improvement and eventual system design. Function models were prepared for each potential improvement concept. A Systems Requirement Document (SRD) was prepared to aid in the development of the state-of-the-art survey.

2.2.9 State-of-the-Art Survey

A questionnaire was developed as a result of the formulation of improvement concepts and was sent to various software houses to determine whether the functionality could be satisfied with commercially available software. After analyzing the State-of-the-Art Survey, the technology voids for IPS design were identified. A State-of-the-Art document was prepared as a result of this activity.

2.2.10 Development of IPS Preliminary Design

A conceptual design was developed in the form of IDEF₀ models with appropriate text and glossary, using the improvement concepts and technology voids as input to this task.

2.2.11 Preliminary Design Comparison to MRPII Concepts

An analysis of industrial users of MRP systems was developed and conducted to determine system benefits. Vendor-supplied MRP packages were evaluated against the functionality specified in the IPS preliminary design. During this process, a Capacity Requirements Planning (CRP) state-of-the-art analysis was completed. Using functional requirements for a CRP package a software questionnaire was developed, and the responses served as the basis of this analysis.

2.2.12 Development of an IPS "To-Be" System Specification (SS) for Production Planning and Control (PP&CS)

The functional requirements were prioritized based on estimated benefits. The technology voids for each requirement were ranked according to the best opportunity to develop the needed technology. The specification included the following requirements:

- Experience and Capability Information
- Lot Sizing Technique
- Level Loading
- Effective Control of Capacity and Resources
- Control Thread Requirements

The system specification document included the definition of the information requirements needed to support the system requirements identified above.

2.2.13 Development of a System Design Specification (SDS) for the "To-Be" PP&CS Prototype

The SDS defined the configuration items (functionality) that needed to be developed to satisfy the system requirements. This document also included the data characteristics, data

requirements, data collection and transfer procedures, inputs, outputs, interfaces, design and construction standards, human engineering and personnel training and quality assurance provisions.

2.2.14 Development of Computer Development Specifications (DS) for the "To-Be" PP&CS

Development Specifications (DS) were developed for each configuration item defined in the System Design Specification. The Development Specifications detailed the system capacities, interface requirements, functional requirements, inputs, processing details, outputs and quality assurance provisions.

2.2.15 Software Design Approach and Implementation Strategy

This activity developed software design procedures, software design approach, detail design assumptions and system implementation strategy for PP&CS.

2.2.16 Development of Heuristic Load Balancing Techniques

A detail manual was constructed to procedurally describe the algorithms and heuristic rules that would be utilized in the software for the loading and balancing of jobs on resources.

2.2.17 Resultant Processing Approach

A detailed approach identifying algorithms and statistical techniques to collect feedback and process the results of the data was accomplished. The design for inputs and outputs for the system were identified, and the ability for trend diagrams to be graphically displayed was described.

2.2.18 Quality Assurance Plan (QAP)

A quality assurance plan for the software development effort was produced. This document addressed the issues of development tools, techniques and methodologies, computer program design, documentation standards, computer program library controls, reviews and audits, configuration management, testing and corrective action procedure.

2.2.19 PP&CS Data Base Approach

A data base schema was developed to support the PP&CS system. The PP&CS data base was constructed using VAX 11 DBMS, a CODASYL-compliant data base management system. The schema detailed the record types, record relationships, information contained within record types, storage areas, physical placement of records, and set characteristics including insertion nodes, record retention and logical ordering.

Section 3

PROJECT ACCOMPLISHMENTS

Project Accomplishments by Work Breakdown Structure

The work breakdown structure (Figure 3-1) for Project Priority 5501 consisted of seven tasks and 26 subtasks. The project was broken down as follows:

Task 1 Program Planning

Subtask 1 — Develop Master Plan and Schedule

Task 2 Manufacturing Planning (MPS)

Subtask 1 — Develop and Understand the MPS Problem

Subtask 2 — Analyze Needs for MPS

Subtask 3 — Build "As-Is" Factory View

Subtask 4 — Build "As-Is" Composite MPS Factory View

Subtask 5 — Formulate Improvement Concepts for MPS

Subtask 6 — Review State-of-the-Art for MPS

Task 3 Process Planning (PPS)

Subtask 1 — Develop and Understand the PPS Problem

Subtask 2 — Analyze Needs for PPS

Subtask 3 — Build "As-Is" PPS Factory View

Subtask 4 — Build "As-Is" Composite PPS Factory View

Subtask 5 — Formulate Improvement Concepts for PPS

Subtask 6 — Review State-of-the-Art for PPS

Task 4 Plan for Manufacture (PMS)

Subtask 1 — Develop and Understand the PMS Problem

Subtask 2 — Analyze Needs for PMS

Subtask 3 — Build "As-Is" PMS Factory View

Subtask 4 — Build "As-Is" Composite PMS Factory View

Subtask 5 — Formulate Improvement Concepts for PMS

Subtask 6 — Review State-of-the-Art for PMS

Task 5 Design IPS

Subtask 1 — Develop "Formulate and Justify Solution" Subplan

Subtask 2 — Establish Preliminary Design

Subtask 3 — Establish Detailed Design

Task 6 Construct, Integrate and Test IPS Subsystem

Subtask 1 — Develop "Construct Integrate and Test" Subplan

Subtask 2 — Construct, Code and Verify IPS Subsystem Prototype

Subtask 3 — Integrate, Test and Validate IPS Subsystem Prototype

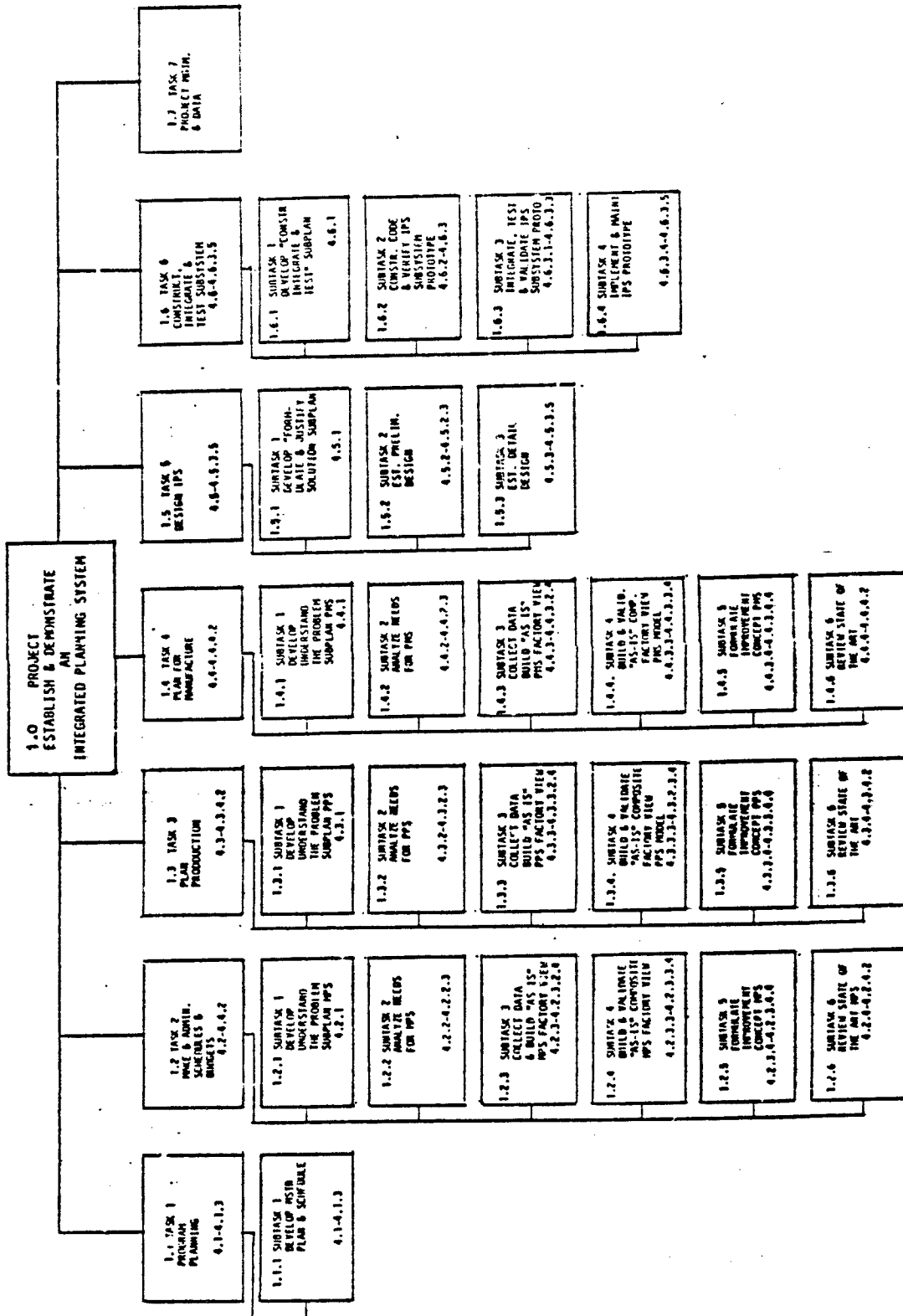


Figure 3-1. Integrated Planning System - Work Breakdown Structure

Subtask 4 — Implement and Maintain IPS Subsystem Prototype

Task 7 Project Management and Data

3.1 TASK 1, SUBTASK 1: DEVELOP MASTER PLAN AND SCHEDULE

3.1.1 Scope

Accomplishments

A review of the draft scope was completed. A revised scope was published in Project Priority 5501's first interim report.

The directly supported nodes were taken from the integration document supplied with the Project Priority 5501 RFP.

An analysis was performed using the Manufacturing Architecture MFG₀ model and specific exceptions were noted and documented in the first interim report.

A master plan and schedule was developed and defined the project objectives, tasks, sub-tasks, schedules, budgets, materials and method, facilities, personnel and deliverables required.

3.2 TASK 2, SUBTASK 1: DEVELOP AND UNDERSTAND THE MANUFACTURING PLANNING SUBTASK (MPS) PROBLEM

3.2.1 MPS Requirements Definition

Accomplishments

A detailed plan was developed with Rockwell International and General Electric to perform requirements definition, Needs Analysis, and state-of-the-art assessment of the "As-Is" MPS arena with emphasis on the formulation of improvement concepts for this task. The plan included training, data collection techniques, model building, validation process, analysis and state-of-the-art review.

The scope of the MPS study effort was developed in the form of an IDEF₀ kit published in the first interim report and was used by Rockwell International and General Electric as the guide for understanding the MPS problem.

3.2.2 Task 2, Subtask 2: Analyze Needs for MPS

3.2.2.1 MPS Needs Analysis

Accomplishments

A Needs Analysis was completed for the MPS task. An understanding of the functional requirements, computer application strategies, interface requirements and problems was developed. Needs were prioritized based on established criteria such as cost drivers, potential benefits, and human factors. The primary needs identified in the MPS arena were as follows:

- Automated Master Schedule and First Article Schedule
- Automated Assembly Build Schedule
- Ability to Establish Optimum Program and Production Lot Sizes

- Automated Center Level Schedules
- Automated Data Collection for Line-of-Balance Statusing
- Provide Computer-Assisted Cost Package Estimation
- Computer-Assisted Optimization of Work Authorization Release Time
- Machine/Tool Load Schedules

Satisfying the above needs indicated a potential savings for a major airplane program to be in excess of \$45 million.

The needs for MPS were prioritized and used in the development of improvement concept design for IPS. The detailed Needs Analysis for MPS was documented in the second IPS interim report (ITR550150002U).

3.2.3 Task 2, Subtask 3: Build "As-Is" MPS Factory View

3.2.3.1 MPS Function and Information Modeling

Accomplishments

An IDEF₀ function model and an IDEF₁ information model were constructed based on the priorities established in the Needs Analysis. It was determined that the process of developing coordinating schedules really encompassed the major needs identified for MPS.

Based on this decision, the function and information modeling effort concentrated on the Develop Coordinating Schedules arena. The top view of the function model is referenced in Figure 3-2, labeled RH1, and Figure 3-3, labeled RH2. The information model overview is referenced in Figure 3-4, labeled RH006; and Figure 3-5, labeled RH008.

The complete IDEF₀ function model kit number AIM550152100 and the IDEF₁ information model kit number AIM550152200 are available in the ICAM library.

The process of MPS factory modeling added 25 bottom-level nodes to the Manufacturing Architecture MFG₀. These added nodes were a result of a further breakdown of activities in the Develop Coordinating Schedules arena.

3.2.4 Task 2, Subtask 4: Build "As-Is" Composite MPS Factory View

3.2.4.1 MPS Composite Factory View

Accomplishments

An IDEF₀ and IDEF₁ model of MPS was completed.

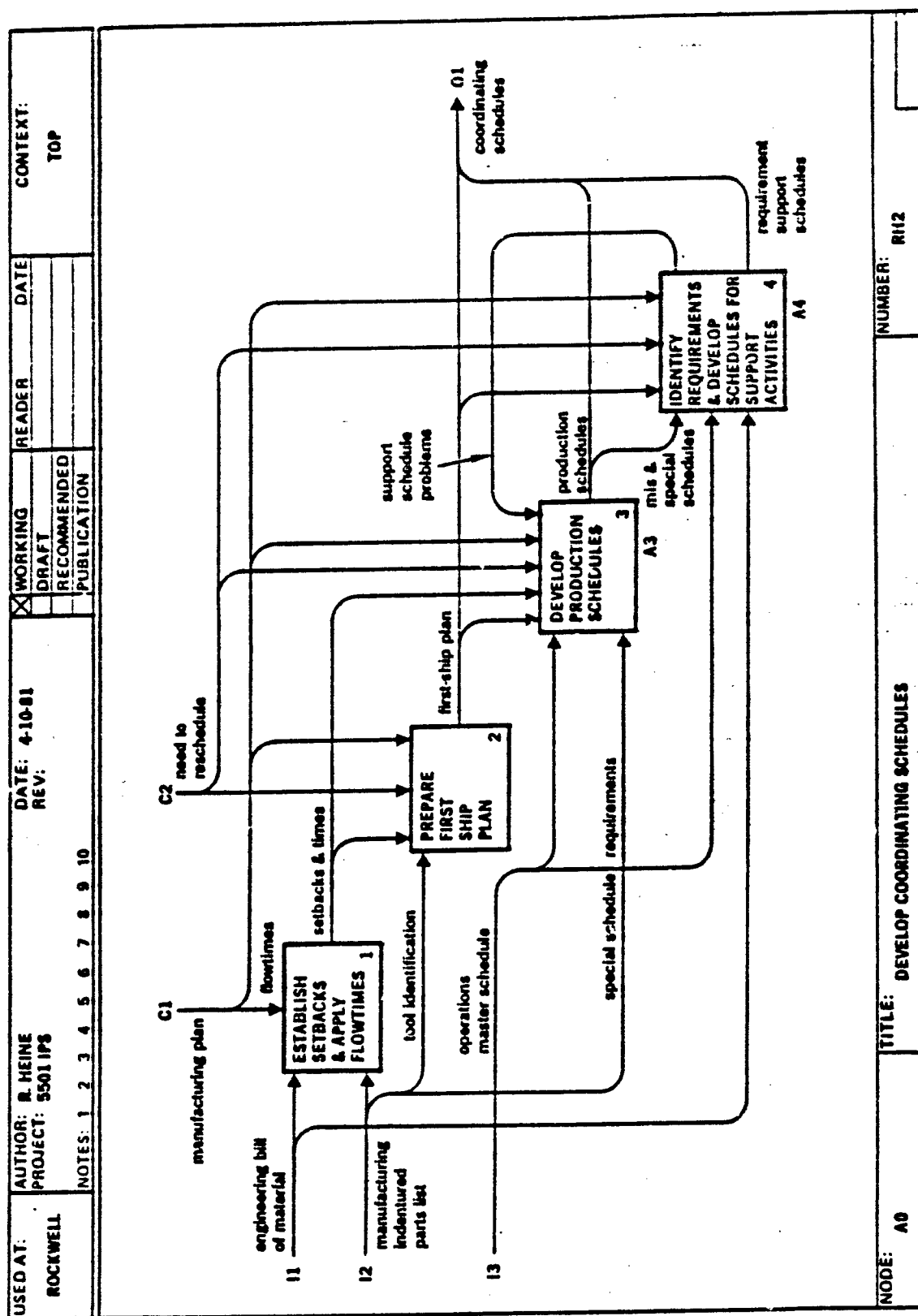
Using the completed Rockwell International factory view of MPS, the balance of the coalition provided their DEF₀ and IDEF₁ data and models of MPS. This effort provided a formal review and consensus that led to concurrence of the coalition on the final composite view models of MPS.

In order to assure that results were achieved in the three major areas, MPS, PPS and MPS the subcontractors expertise was utilized in a manner which minimized their detail modelling efforts. The technique allowed each of the subcontractors to concentrate on a specific area and still provide significant input to the other areas.

USED AT: ROCKWELL	AUTHOR: R. HEINE PROJECT: 5501 IPS DATE: 4-10-81 REV:	WORKING <input checked="" type="checkbox"/> DRAFT <input type="checkbox"/> RECOMMENDED <input type="checkbox"/> PUBLICATION	READER DATE	CONTEXT: NONE
<div style="display: flex; justify-content: space-around; align-items: center;"> <div style="text-align: center;"> <p>engineering bill of material manufacturing indented parts list, tool ident, special schedule requirements</p> <p>operations master schedule</p> </div> <div style="border: 1px solid black; padding: 10px; text-align: center;"> <p>DEVELOP COORDINATING SCHEDULES</p> </div> <div style="text-align: center;"> <p>need to reschedule</p> <p>coordinating schedules</p> </div> </div> <p style="margin-top: 20px;"> PURPOSE: TO DEVELOP A DETAILED ROCKWELL INTERNATIONAL FACTORY VIEW OF THOSE FUNCTIONS JUDGED MOST VITAL TO THE IPS A2 NODE NEEDS ANALYSIS. MORE SPECIFICALLY, THE PURPOSE INCLUDES IDENTIFYING AND UNDERSTANDING THOSE DATA AND PROCEDURES THAT SHAPE THE SCHEDULE AND CONTROL ACTIVITY WITHIN THE COORDINATING SCHEDULES AREA. THESE FUNCTIONS FALL WITHIN THE SCOPE OF THE ABOVE A-0 DIAGRAM, WHICH IS SIMILAR TO CV A22. VIEWPOINT: THE MODEL WILL BE DEVELOPED FROM THE VIEWPOINT OF THE FUNCTIONAL MANAGER OF OPERATIONS. OPERATIONS, IN THIS CONTEXT, ENCOMPASSES MANUFACTURING AND THOSE ADMINISTRATIVE DEPARTMENTS THAT SUPPORT MANUFACTURING </p>				
NODE: A-0	TITLE: DEVELOP COORDINATING SCHEDULES			NUMBER: RH1

FORM 1002, 1-85 NEW 4-81

Figure 3-2. Develop Coordinating Schedules



NUMBER: R112

TITLE: DEVELOP COORDINATING SCHEDULES

NODE: A0

FORM 1002-N-49 NEW 4-81

Figure 3-3. Develop Coordinating Schedules

ICAM Analysis Sheet

[illegible]

Figure 3-4. Kit Overview

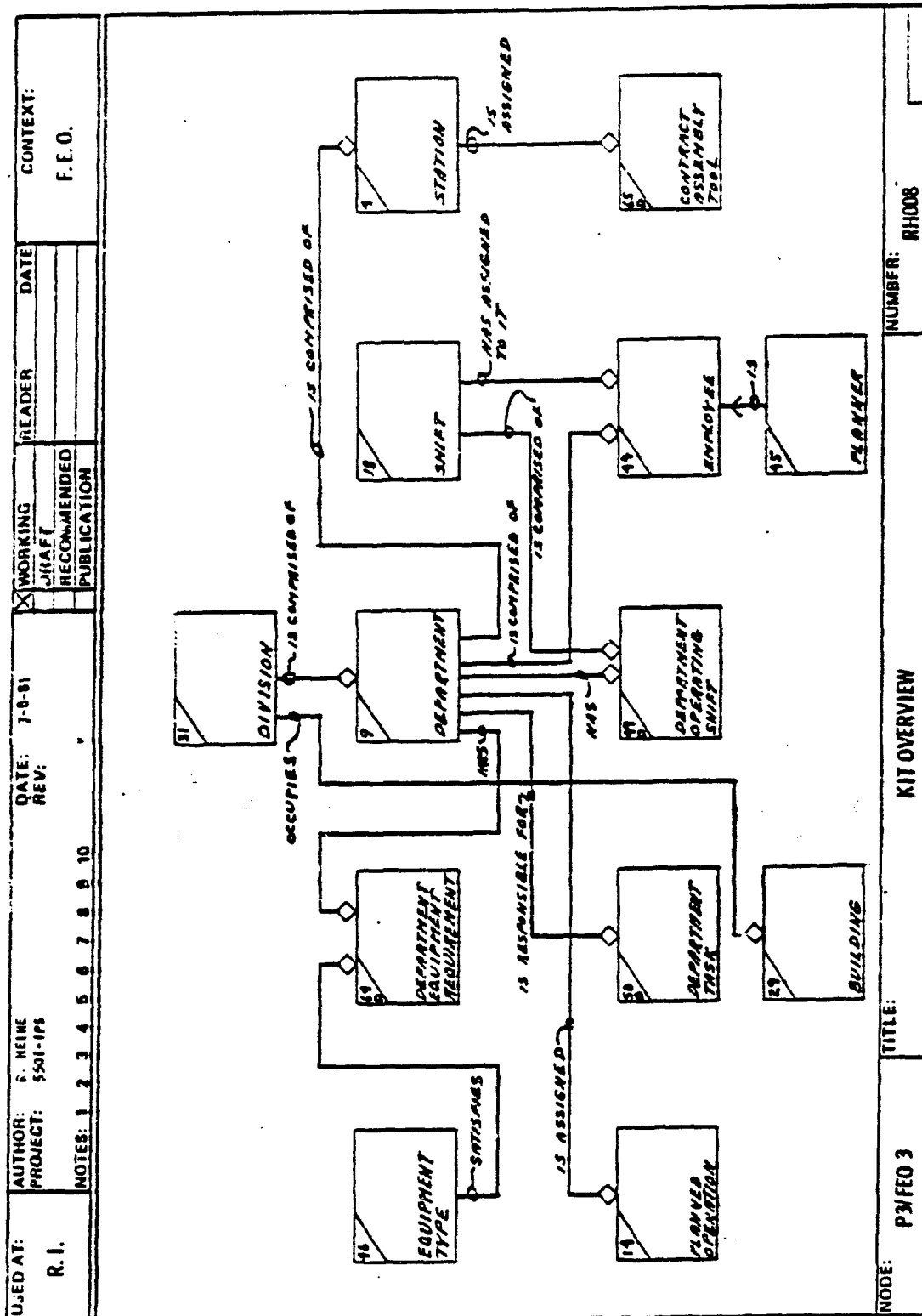


Figure 3-5. Kit Overview

Figure 3-6 represents the technical IDEF₀ and IDEF₁ modeling approach used by General Electric and its coalition consisted of the following steps:

- Three independent IDEF₀ shallow factory view models of integrated planning were built by the subsystem principal subcontractors.
- A composite model was derived from the shallow factory views.
- Additional factory view IDEF₀ modeling was provided, detailing extensions to the composite "top," with each subsystem principal subcontractor concentrating on an area of planning expertise (Manufacturing Planning, Process Planning, or Plan for Manufacture).
- Each subsystem principal subcontractor modeled less extensively in IDEF₀ one other area as directed by General Electric.
- Each subsystem principal subcontractor produced graphical IDEF₁ models corresponding to the data associated with the functions that they modeled in IDEF₀.
- A baseline composite view IDEF₀ model was developed from the factory view IDEF₀ models.
- A baseline composite view IDEF₁ model was developed from the factory view IDEF₁ models, with subsequent detailed documentation of attribute classes carried out by coalition members during the composite modeling task.
- Baseline models were formally reviewed by coalition members and the Air Force PMO, leading to concurrence on final composite view IDEF₀ and IDEF₁ models.

The modeling efforts were carried out by "chief author" teams, as illustrated by Figure 3-7. The team consisted of a chief author experienced in IEDF₀ and/or IDEF₁ along with one or more additional persons with IDEF experience, depending on the model being built. Under this approach, the principal aerospace subcontractor and IDEF consultant formed two modeling teams: one IDEF₀ team and one IDEF₁ team. The two teams were led by a chief author who was responsible for understanding both models produced under his or her direction, and their interrelationships. General Electric, with this approach, facilitated the development of the IDEF₀ and IDEF₁ models without sacrificing the conceptual independence of the models. The chief authors utilized the IDEF₀ models for guidance in developing IDEF₁ models, and called upon their familiarity with both models in subsequently correlating the IDEF₀ and IDEF₁ models to resolve terminology differences.

3.2.5 Task 2, Subtask 5: Formulate Improvement Concepts for MPS

3.2.5.1 MPS Improvement Concepts

Accomplishments

The improvement concepts prioritized for MPS were developed from a major category list of 15 technologies that were compiled from the Needs Analysis. The result of this analysis indicated that the most important improvements in MPS technology were:

- Scheduling Capabilities
- Resource Allocation and Control

The composite "As-Is" factory model for MPS was used to determine improvement concepts for further study and evaluation. The process by which the improvement concepts were developed for MPS was as follows:

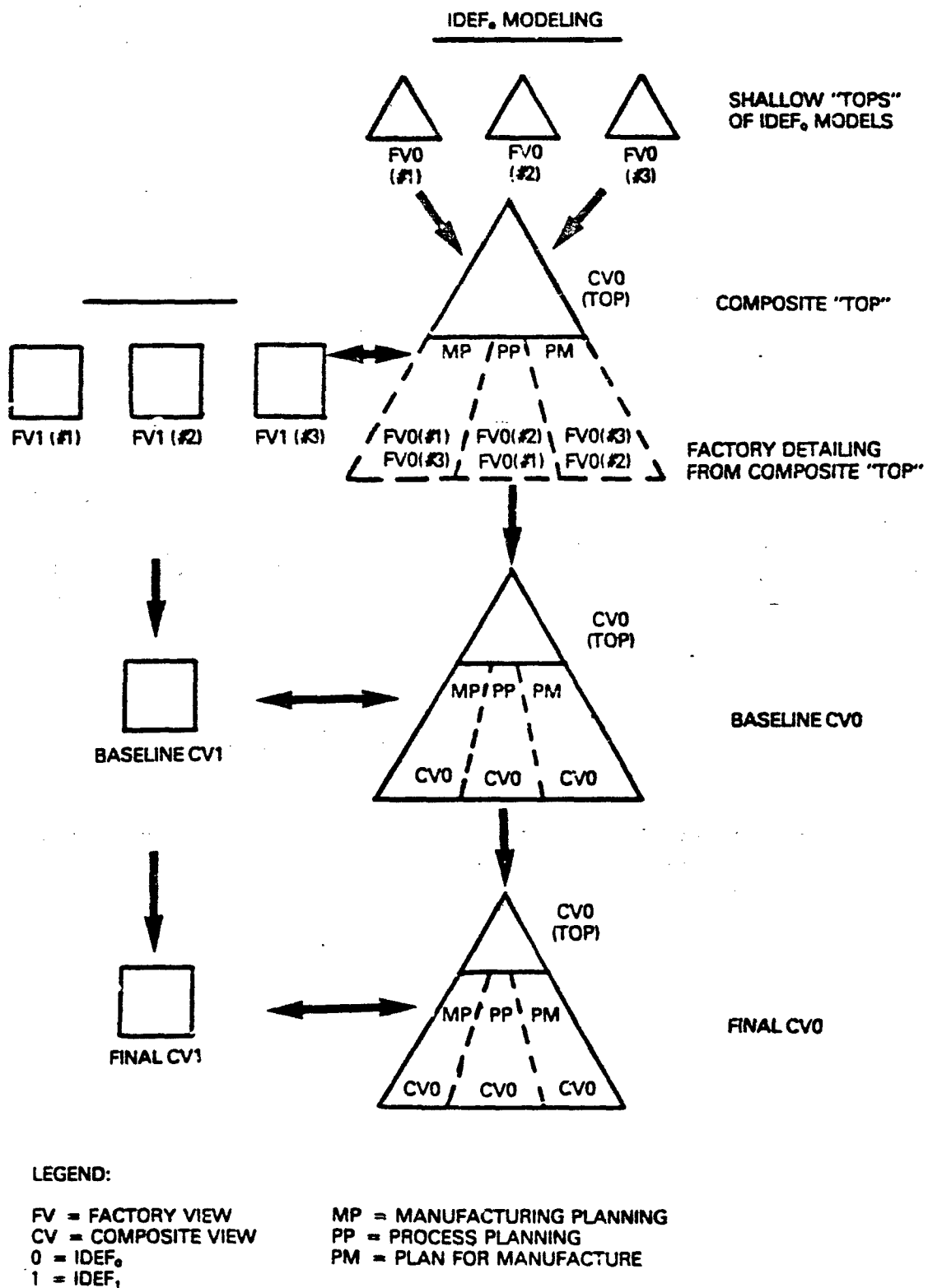


Figure 3-6. IDEF₀ Modeling

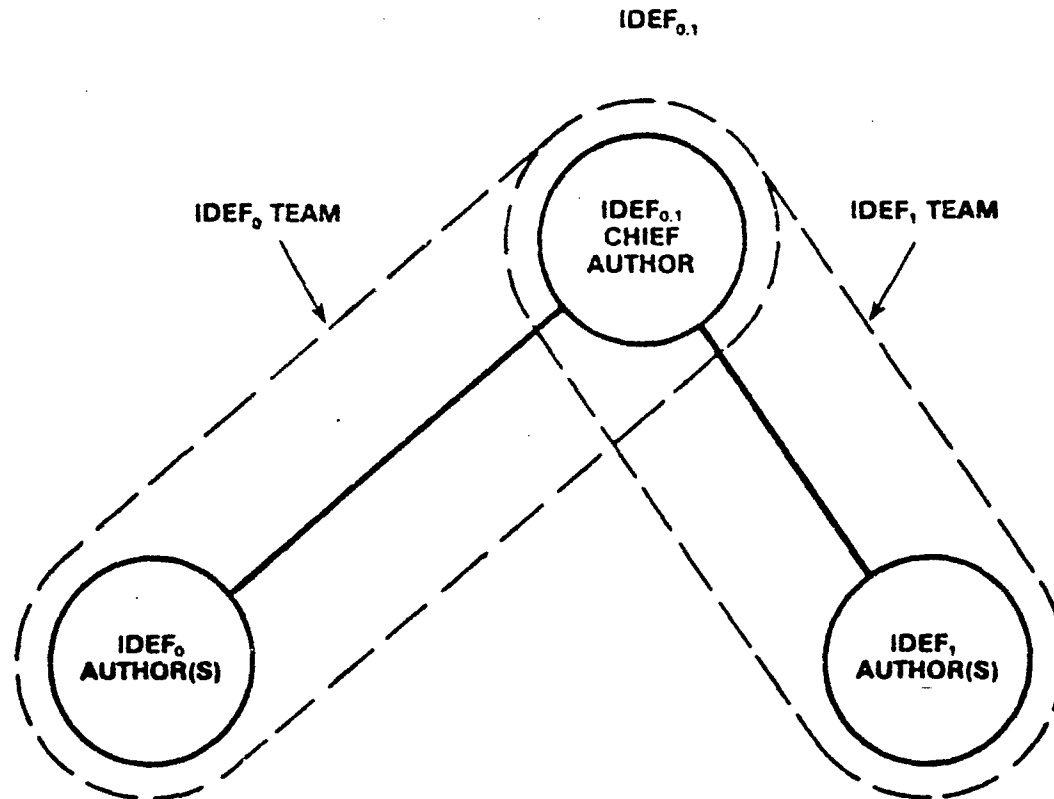


Figure 3-7. Chief Author Team

- Identify performance measures for MPS via Needs Analysis, State-of-the-Art Survey, and the Manufacturing composite view architecture.
- Develop an improvement concept and discuss in scenario form the details and support the activity with an IDEF₀ function model.
- Compare the improvement concepts identified with information received from the state-of-the-art questionnaire results.

An example of improving scheduling capabilities and resource allocation and control is depicted in Figures 3-8, 3-9, and 3-10, referenced IC13, IC14, and IC15.

The total development details related to MPS improvement concepts are included in the 15 major technologies contained in the third IPS interim report (ITR550150003U).

3.2.6 Task 2, Subtask 6: Review State of the Art for MPS

3.2.6.1 MPS State-of-the-Art Survey

Accomplishments

The State-of-the-Art Survey was compared to the improvement concepts and resulted in the identification of requirements for future preliminary design of MPS. This process identified technology voids and provided the ability to prioritize the voids in available software. The method that was used to perform the survey is depicted in Figures 3-11 and 3-12.

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		NOTES: 1 2 3 4 5 6 7 8 9 10													


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graph TD
    CAPACITY --> LTL[LEVEL THE LOAD]
    PS[PRODUCTION SCHEDULE] --> LTL
    EXP[EXPERIENCE] --> LTL
    SIM[SIMULATION] --> LTL
    LTL -- AO --> LLS[LEVEL LOADED PRODUCTION SCHEDULE]
    
```


PURPOSE: To illustrate the improvement concept of leveling the shop load.
VIEWPOINT: The viewpoint is that of a designer conceptualizing improvements within the planning system.

NODE: A-0		TITLE: LEVEL THE LOAD (CONTEXT)		NUMBER: IC13	
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Figure 3-8. Level the Load (Context)

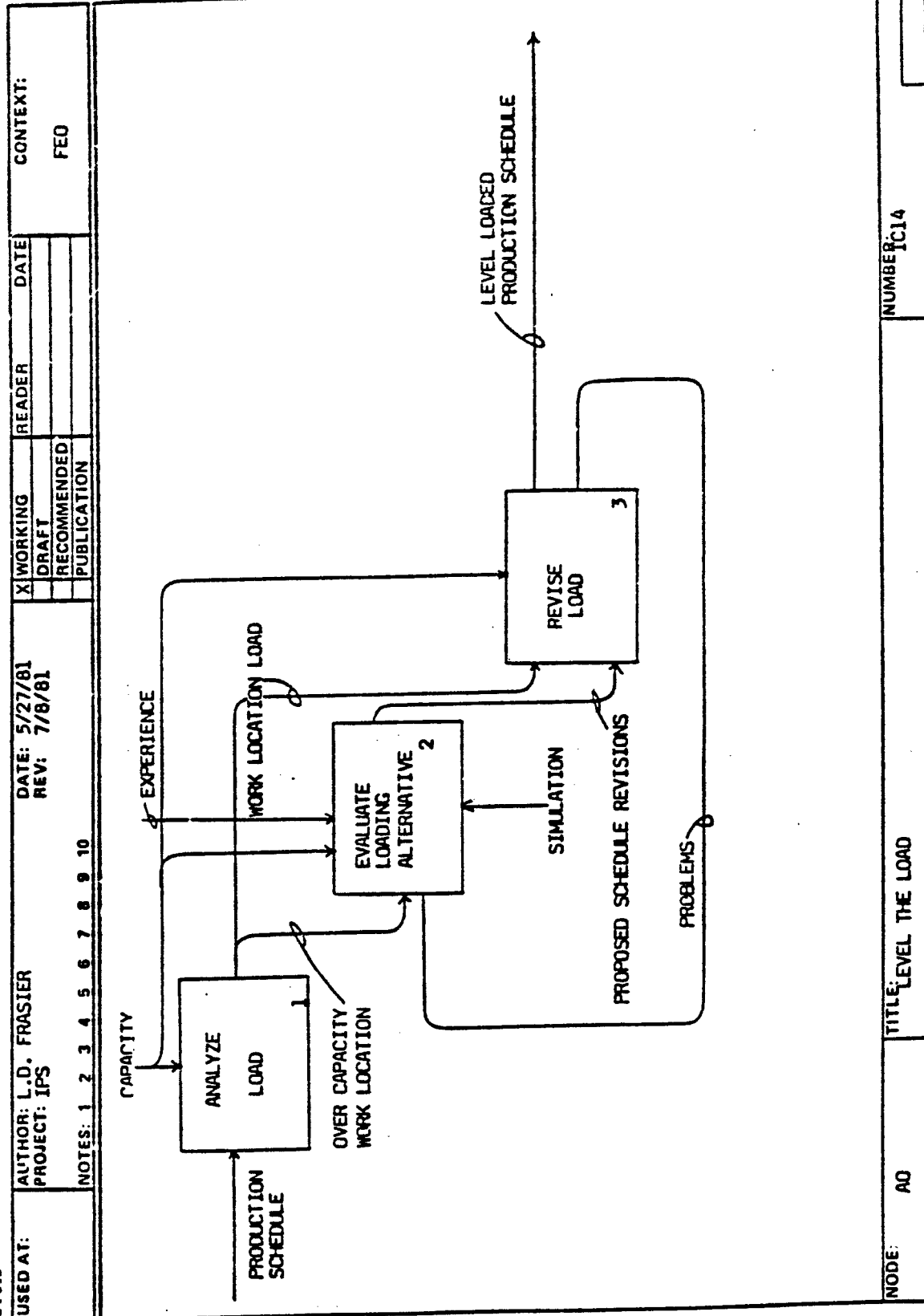


Figure 3-9. Level the Load

21424

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	NOTES: 1 2 3 4 5 6 7 8 9 10					TEXT

5. IMPROVEMENT CONCEPT: A LOADING SIMULATION MECHANISM TO SUPPORT CAPACITY REQUIREMENTS PLANNING

Capacity planning is concerned with the determination of the labor and equipment resources needed to meet the production schedule. Without a technique for "rough cut" load leveling prior to release of the Production Schedule, the factory is left to its own resources to deal with the obvious or hidden "peaks and valleys" in the demand for labor and machines at various points in time.

In order to produce a feasible schedule, a loading simulation mechanism to support capacity planning (Figure IC13) is envisioned. Figure IC14 further breaks down this concept into three functions to support the activity Level the Load: Box 1, Analyze Load, depicts the act of checking the production schedule against the available plant capacity in order to identify locations which are overloaded. These overloaded locations are then input to Box 2, Evaluate Loading Alternative. This activity, controlled by both capacity of the shop and user experience in the selection of an alternative resource, produces the probable effect of that change before it is actually carried out on the shop floor. Finally, the load is revised (Box 3) producing either a new production schedule which is level loaded or scheduling conflicts, problems, etc., which then need re-evaluation and hence re-simulation (Box 2).

Simulation as a mechanism could aid in the identification of critical work locations, under-utilized resources, and improper lot sizes. The performance measures identified with this module are:

- Percentage reduction in capital investment.
- Increased number of inventory turns.
- Percentage reduction in labor.
- Percentage reduction in overtime.
- Percentage reduction in idle time.
- Percentage reduction in late delivery.

NODE:	TITLE: LEVEL THE LOAD	NUMBER: IC15
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Figure 3-10. Level the Load

USED AT:	AUTHOR: G.F. ROBERTS PROJECT: IPS	DATE: 4/29/81 REV: 10/6/81	WORKING <input checked="" type="checkbox"/> DRAFT <input type="checkbox"/> RECOMMENDED <input type="checkbox"/> PUBLICATION	READER	DATE	CONTEXT: TOP
<div style="display: flex; justify-content: space-between;"> <div style="width: 20%;"> NOTES: 1 2 3 4 5 6 7 8 9 10 </div> <div style="width: 80%; text-align: center;"> <pre> graph TD A[PRIORITYZED IMPROVEMENT CONCEPTS] --> D[PERFORM ICAM SOA SURVEY] B[SOW REQUIREMENT FOR SURVEY] --> D C[IPS NEEDS ANALYSIS] --> D E[COMPOSITE ARCHITECTURE] --> D F[INDUSTRY-EXPERT OPINION] --> D D --> G[SURVEY QUESTIONNAIRE] D --> H[VENDOR RESPONSES] </pre> </div> </div>						
<p>FIGURE 1</p> <p>PURPOSE: The purpose of the ICAM SOA survey is to determine the extent to which existing manufacturing software systems satisfy IPS needs.</p> <p>VIEWPOINT: This survey was conducted from the viewpoint of an information systems designer responsible for developing and implementing the IPS system.</p>						
NODE: A-O	TITLE: CONTEXT: PERFORM ICAM SOA SURVEY				NUMBER: GR-1	

Figure 3-11. Context: Perform ICAM SOA Survey

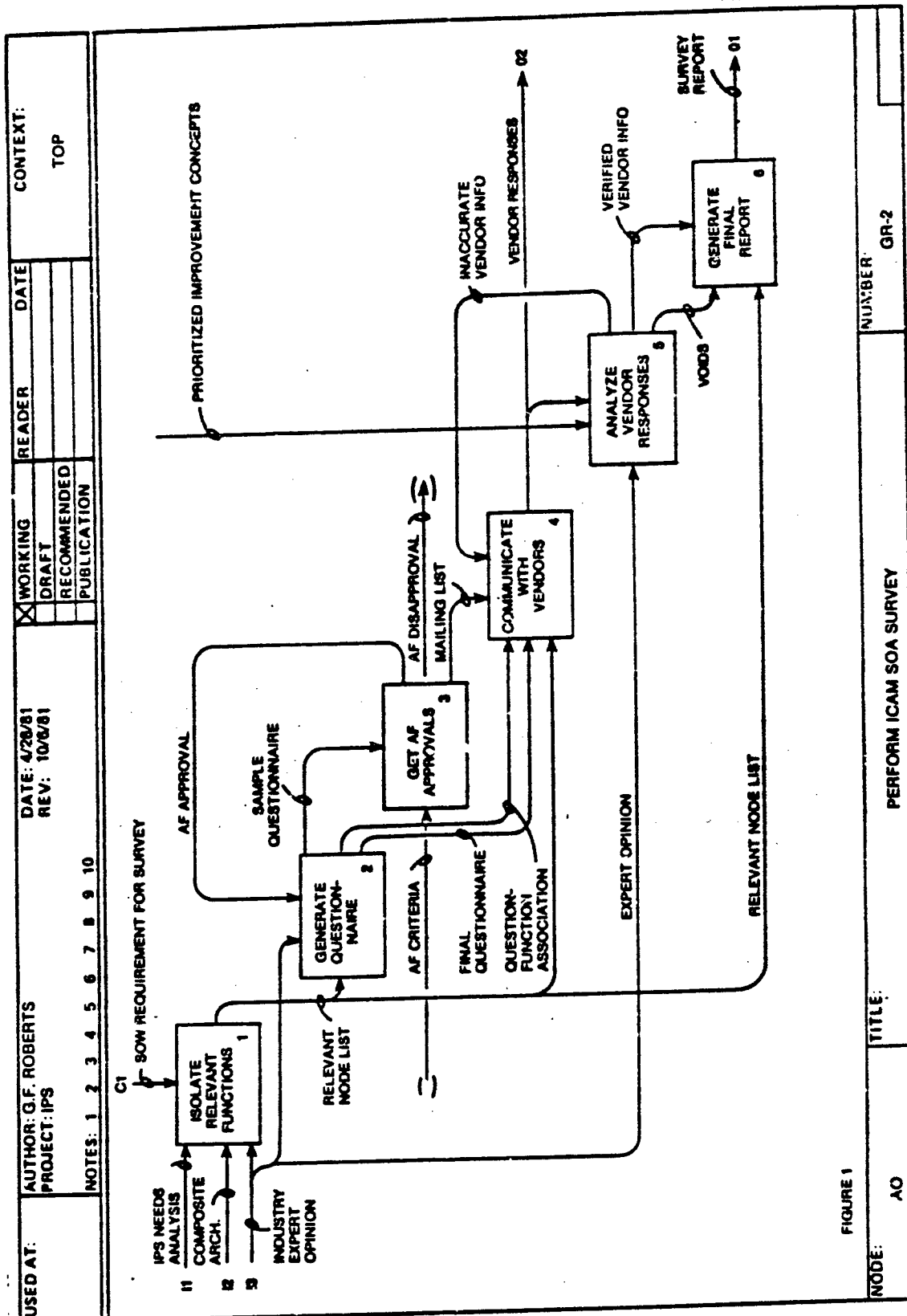


Figure 3-12. Perform ICAM SOA Survey

The State-of-the-Art Survey was conducted for MPS via a questionnaire, which was developed to identify interfaces and relationships of planning and control. The survey was conducted over a period of two months to ensure sufficient industry feedback and coverage. The sources of data were evaluated in order to identify and provide a basis for needed technology developments.

An initial list of 47 potential software suppliers was assembled, from which a mailing list of 17 was considered. The survey document and mailing list were presented to the Air Force for approval. Each company on the list was contacted by phone prior to the mailing to determine whether it would complete the survey. A specific individual was identified at each company to receive the survey and serve as a contact for verification of receipt and any other required coordination.

Of the 17 companies selected for the State-of-the-Art Survey, nine actually responded.

3.2.6.2 Weighted Analysis Technique

There were approximately 15 questions per topic (150 questions total) in the questionnaire. A scale for responding was included for each question. The scale consisted of three major points: "not at all" (low end of scale), "partial" (midpoint), and "complete" (high end), indicating the degree to which a particular topical question was covered by a vendor's software.

Following the receipt of the vendor's completed survey, the answers were weighted by assigning values from 0 to 4 to the graduations on the scale (see Figure 3-13).

Each respondent's check mark on the scale was analyzed and a corresponding value was assigned. Every question included within a functional area could be rated at most a value of 4; hence, if there were 15 questions in a particular functional area, the maximum score would be 60. Therefore, if a particular respondent checked "partial" for every question, the respondent's score would be 30.

The resulting percentage of the SOA available from that respondent for that functional area would be 50%, as calculated by the following equation:

$$\% \text{ SOA} = \frac{\text{RESPONDENT SCORE}}{\text{Total Score Possible}} \times 100$$

The final state-of-the-art (SOA) document SAR 550150000 contains the scores for all respondents for a particular functional area on those figures entitled, "Weighted Values for Each Question and Percentage SOA Available by Respondent." In addition, the resulting percentage representing the amount of the state-of-the-art software that the respondent currently has available is displayed in graphic form in the same document.

A summary of respondents' available software functionality they thought could satisfy the major 15 categories of technologies appears in Figure 3-14.

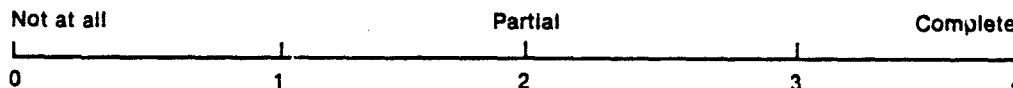


Figure 3-13. Weighted Scale

IPS Functional Area	Number of Respondents				
	NOT AT ALL	25	PARTIAL	50	75 100 COMPLETE
1. Computer-Assisted Build Sequence Optimization	0	1	0	2	2 4
2. Experience and Capability	2	0	4	2	1
3. Computer-Aided Detail Part Process Planning	1	3	3	2	0
4. Computer-Assisted First Article Schedule Prep	0	3	3	3	0
5. Computer-Assisted Calculation of Lot Sizes	0	0	2	6	1
6. Simulation of Alternative Strategies	2	3	1	3	0
7. Computer-Assisted Line-of-Balance and Display	5	4	0	0	C
8. Level Loading	1	4	3	0	1
9. Automatic Reschedule of Released Work Orders	0	3	3	1	2
10. Structure Product According to Process	2	3	3	1	0
11. Computer-Aided Assembly Process Planning	1	4	1	3	0
12. Structure Resource Requirements	0	2	1	3	3
13. Effectivity Control	0	2	2	3	2
14. Automated Time Standards	1	6	1	0	1
15. Tool Control	2	1	5	1	0

Figure 3-14. Percentage of Functionality Reflected in the State-of-the-Art Survey for all Respondents

3.3 TASK 3, SUBTASK 1: DEVELOP AND UNDERSTAND THE PLAN PRODUCTION SUBTASK (PPS) PROBLEM

3.3.1 Understand the Problem Plan

Accomplishments

A detailed plan was developed with General Dynamics and General Electric to perform requirements definition, Needs Analysis, and state-of-the-art assessment of the "As-Is" PPS arena with emphasis on the formulation of improvement concepts for the PPS task. The plan included training, data collection techniques, model building, validation process, analysis, and state-of-the-art review.

The scope of the PPS study effort was developed in the form of an IDEF₀ kit and was used by General Dynamics and General Electric as the guide for understanding the PPS problem.

3.3.2 Task 3, Subtask 2: Analyze Needs for PPS

3.3.2.1 PPS Needs Analysis

Accomplishments

A Needs Analysis was completed for the PPS task. An understanding of the functional requirements, computer application strategies, interface requirements, and problems was developed. Needs were prioritized based on established criteria such as cost drivers, potential benefits, and human factors. The primary needs identified in the PPS arena by General Dynamics were as follows:

- Reconciliation of Engineering Releases
- Automated Assembly Part Planning
- Automated Detail Part Planning
- Automated Application of Work Measurement Standards
- Valid and Accurate Facilities and Resource Management Information

The above needs for PPS were prioritized and used in the development of improvement concepts design for IPS.

If the needs for PPS could be satisfied, a savings of \$1 Million would be possible.

The detailed Needs Analysis for PPS was documented in the second IPS interim report (ITR550150002U).

3.3.3 Task 3, Subtask 3: Build "As-Is" PPS Factory View

3.3.3.1 PPS Function and Information Models

Accomplishments

An IDEF₀ function model and an IDEF₁ information model were constructed based on the priorities established in the Needs Analysis. It was determined that the results of the Plan Production modelling area encompassed the major needs identified for PPS.

Based on the modelling efforts, the function and information models concentrated on the Reconciliation of Engineering Release arena. The top view of the function model is referenced in Figure 3-15 labeled SMS1, and Figure 3-16, labeled SMS2.

The information model overview is referenced in Figure 3-17.

The complete IDEF₀ function model kit number AIM 550153100 and the IDEF₁ information model kit number AIM 550153200 are available in the ICAM library.

The process of PPS factory modeling added 34 bottom-level nodes to the Manufacturing Architecture MFG₀. These added nodes were a result of a further breakdown of activities "Control Planning" and "Determine Detail Method of Manufacture."

3.3.4 Task 3, Subtask 4: Build "As-Is" Composite PPS Factory View

3.3.4.1 PPS Composite Factory View

Accomplishments

Using the completed General Dynamics factory view of PPS, the balance of the coalition provided their IDEF₀ and IDEF₁ data and models of PPS. This process provided a formal review and consensus that led to concurrence of the coalition on the final composite view models of PPS.

The composite modeling approach for PPS was similar to the process identified in paragraph 3.2.4 for MPS.

3.3.5 Task 3, Subtask 5: Formulate Improvement Concepts for PPS

3.3.5.1 PPS Improvement Concepts

Accomplishments

The improvement concepts prioritized for PPS were developed from a major category list of 15 technologies. The results of this analysis indicated that the most important improvements in PPS technology were:

- Level Shop Load
- Effectivity Change Control

The composite "As-Is" factory model for PPS was used to determine improvement concepts for further study and evaluation. The process by which the improvement concepts were developed for PPS was similar to the technique used for MPS in paragraph 3.2.5.1.

The detailed information related to PPS improvement concepts is included in the third IPS interim report (ITR550150003U).

3.3.6 Task 3, Subtask 6: Review State of the Art for PPS

3.3.6.1 PPS State-of-the-Art Survey

Accomplishments

The State-of-the-Art Survey was conducted for PPS via a questionnaire. The process for development of the questionnaire and the survey technique was similar to MPS paragraph 3.2.6. The responses received regarding Effectivity Change Control for engineering changes indicated a lack of accountability and traceability in the various software packages reviewed.

USED AT: GDFW	AUTHOR: S. H. SMITH PROJECT: JPS 5501		DATE: 2/23/81 REV: 5/15/81		WORKING DRAFT RECOMMENDED PUBLICATION		READER		DATE		CONTEXT: NONE	
	NOTES: 1 2 3 4 5 6 7 8 9 10											

CHANGE REQUESTS

ENG. RELEASE

PLAN

PRODUCTION

SCHEDULES, BUDGETS,
STATUS, COST

MFG. PLAN

APPROVED
PROCESSING MAT'L

RESOURCE
CHARACTERISTICS

MOAK PACKAGES

ENG. CHANGE REQUEST

PURPOSE: TO DESCRIBE THE ACTIVITIES AND INTERFACES OF THE
PRODUCTION PLANNING FUNCTION AT GD/FW, USING IDEF METHODOLOGY

VIEWPOINT: THE MODEL WILL BE DEVELOPED FROM THE PERSPECTIVE OF THE
"PLAN PRODUCTION" SYSTEM DESIGNER FOR GD/FW

MODE: A-0	TITLE: PLAN PRODUCTION	NUMBER: SMS 1	2
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Figure 3-15. Plan Production

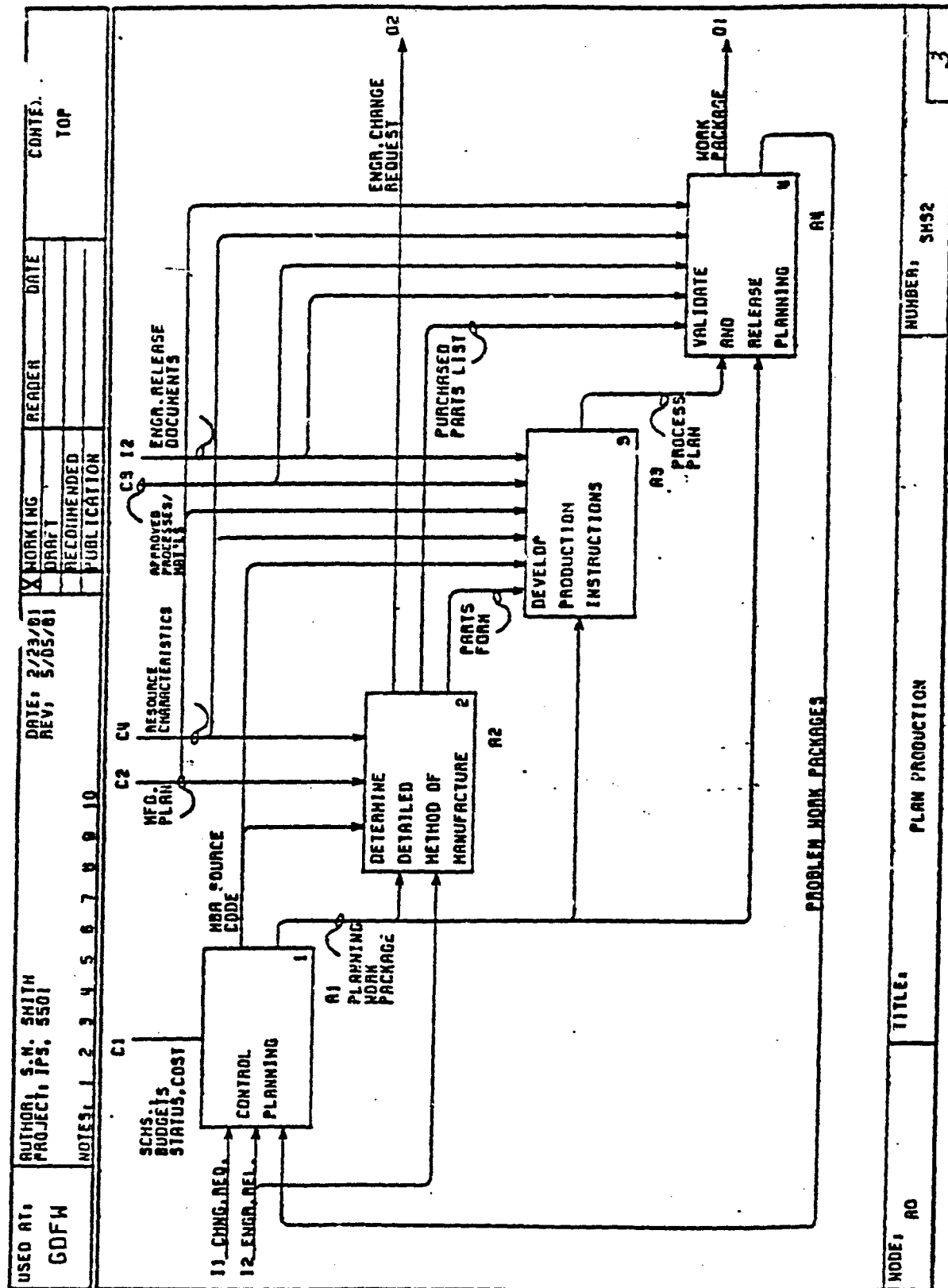
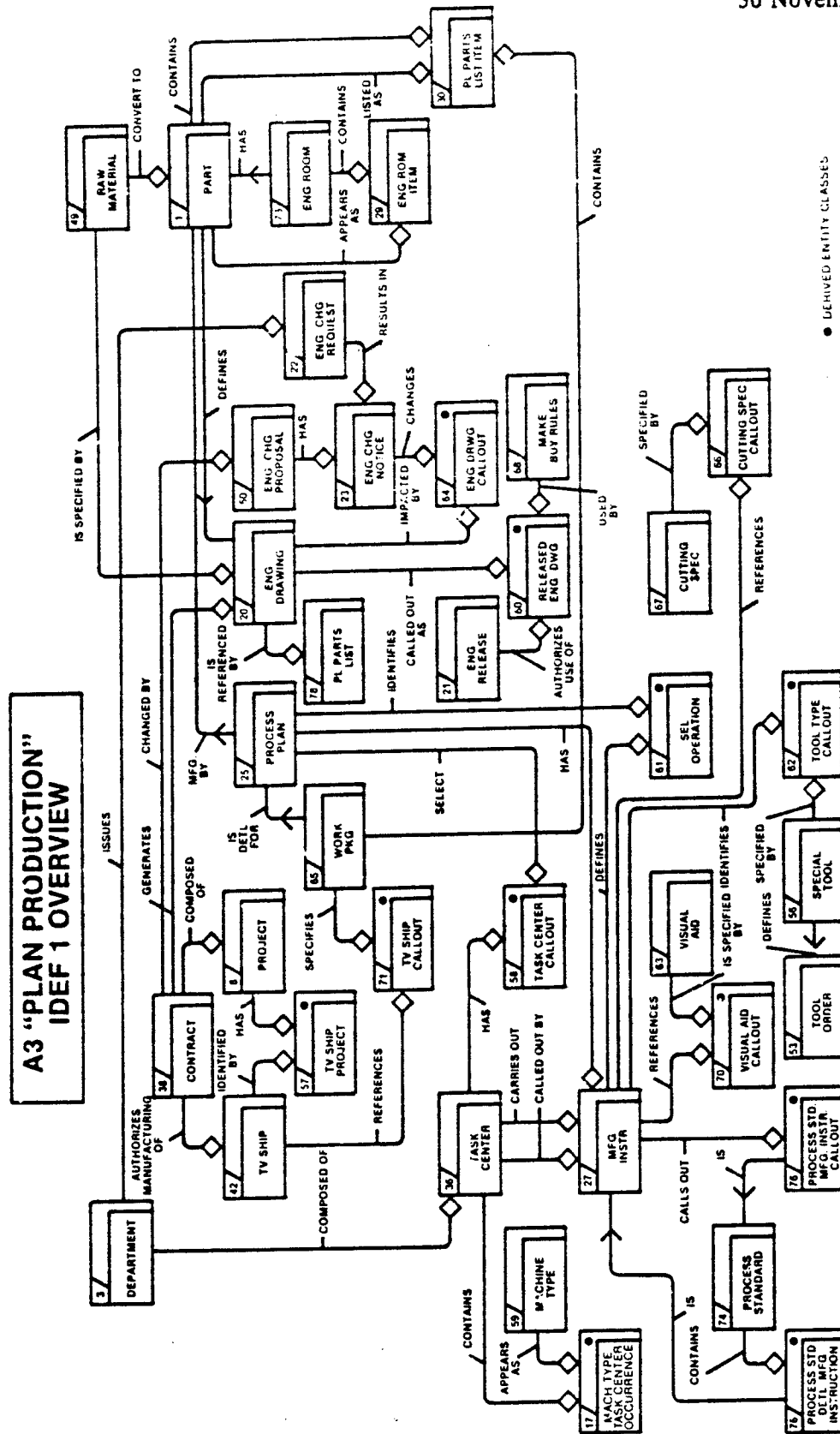


Figure 3-16. Plan Production



• DERIVED ENTITY CLASSES

Figure 3-17. A3 "Plan Production" IDEF₁ Overview

This input provided a high order of priority for development of this technology void for system design of IPS. A complete copy of the survey questions are contained in the third IPS interim report (ITR550150003U).

3.4 TASK 4, SUBTASK 1: DEVELOP AND UNDERSTAND THE PLAN FOR MANUFACTURE SUBTASK (PMS) PROBLEM

3.4.1 PMS Understand the Problem Plan

Accomplishments

A detailed plan was developed with Northrop Corporation and General Electric to perform requirements definition, Needs Analysis, and state-of-the-art assessment of the "As-Is" PMS arena with emphasis on the formulation of improvement concepts for this task. The plan included training, data collection techniques, model building, validation process, analysis, and state-of-the-art review.

3.4.2 Task 4, Subtask 2: Analyze Needs for PMS

3.4.2.1 PMS Needs Analysis

Accomplishments

A Needs Analysis was completed for the PMS task. An understanding of the functional requirements, computer application strategies, interface requirements, and problems was developed. Needs were prioritized based on established criteria such as cost drivers, potential benefits, and human factors. The primary needs identified in the PMS arena by Northrop Corporation were as follows:

- Tooling History and Tooling Engineering Data
- Development of Selected Structure and Method of Manufacture
- Valid Engineering Output
- Capability to Assemble and Disseminate Product Design Release Schedules
- Budget Preparation
- Available Capability and Performance Status
- Flexible Retrieval of Information
- Consistent Application of Time Standards
- Responsive Manual Systems
- Control of Engineering Changes

The above needs indicated a potential savings in excess of \$2 million.

The needs for PMS were prioritized and used in the development of component concept design for PMS. The detailed Needs Analysis for PMS was documented in the second IPS interim report (ITR550150002U).

3.4.3 Task 4, Subtask 3: Build "As-Is" PMS Factory View

3.4.3.1 PMS Function and Information Models

Accomplishments

An IDEF₀ function model and an IDEF₁ information model were constructed based on the priorities established in the Needs Analysis. It was determined that Control of Engineering Changes and historical information would establish the modeling activity.

Based on this decision, the function and information modeling effort concentrated in the above areas.

The top view of the function model is referenced in Figure 3-18, labeled WP11, and Figure 3-19, labeled WP12. The information model overview is referenced in Figure 3-20, labeled WP42.

The complete IDEF₀ function model kit number AIM550151100 and the IDEF₁ information model kit number AIM 550151200 are available in the ICAM library.

The process of PMS factory modeling added 32 bottom-level nodes to the Manufacturing Architecture MFG₀. These added nodes were a result of a further breakdown of activities in the Estimate Resource Needs and Development of a Production Plan.

3.4.4 Task 4, Subtask 4: Build "As-Is" Composite PMS Factory View

3.4.4.1 PMS Composite Factory View

Accomplishments

A PMS Composite Factory View was completed.

Using the completed Northrop Corporation factory view of PMS, the balance of the coalition provided their IDEF₀ and IDEF₁ data and models of PMS. This process provided a formal review and consensus that led to concurrence of the coalition on the final composite view models of PMS.

The composite modeling approach used by General Electric and its coalition was similar to the MPS process described in paragraph 3.2.4.

3.4.5 Task 4, Subtask 5: Formulate Improvement Concepts For PMS

3.4.5.1 PMS Improvement Concepts

Accomplishments

The improvement concepts prioritized for PMS were from a major category list of 15 technologies. The results of this analysis indicated that the most important improvements in PMS technology were:

- Control of Engineering Change
- Available Capability and Performance Status

The composite "As-Is" factory model for PMS was used to determine improvement concepts for further study and evaluation. The process by which the improvement concepts were developed for PMS was similar to MPS described in paragraph 3.2.5.

ICAM DIAGRAM SHEET Form 31-227 (Rev. 8-83)		AUTHOR: D. A. Poland		DATE: 12-11-80		WORKING		READER		DATE		CONTEXT:	
PROJECT: IPS 5501		REV: 4-13-81		DRAFT		RECOMMENDED						O O O	
NOTES: 1 2 3 4 5 6 7 8 9 10													
<p>PLAN FOR MANUFACTURE</p> <p>product design</p> <p>proposed MFG. plan</p> <p>design revisions</p> <p>PROD. MFG. REQTS. (customer requirements)</p> <p>basic assumptions memo</p> <p>experience & capability information</p> <p>engineering change request (ECP Proposal)</p> <p>manufacturing plan</p> <p>AO</p>													
<p>PURPOSE: To scope the point of departure for defining Northrop Aircraft Division activities which encompass portions of Proposal Preparation and Manufacturing Plan Creation. This provides the means of modeling Northrop's "As-Is" plan for manufacture and referencing it to the CV Architecture.</p>													
<p>VIEWPOINT: This model will be developed from the viewpoint of the Project Planning Management of Northrop Aircraft Division.</p>													
NODE: NIPS/A-0		TITLE: Plan for Manufacture						NUMBER: WP 11					

Figure 3-18. Plan for Manufacture

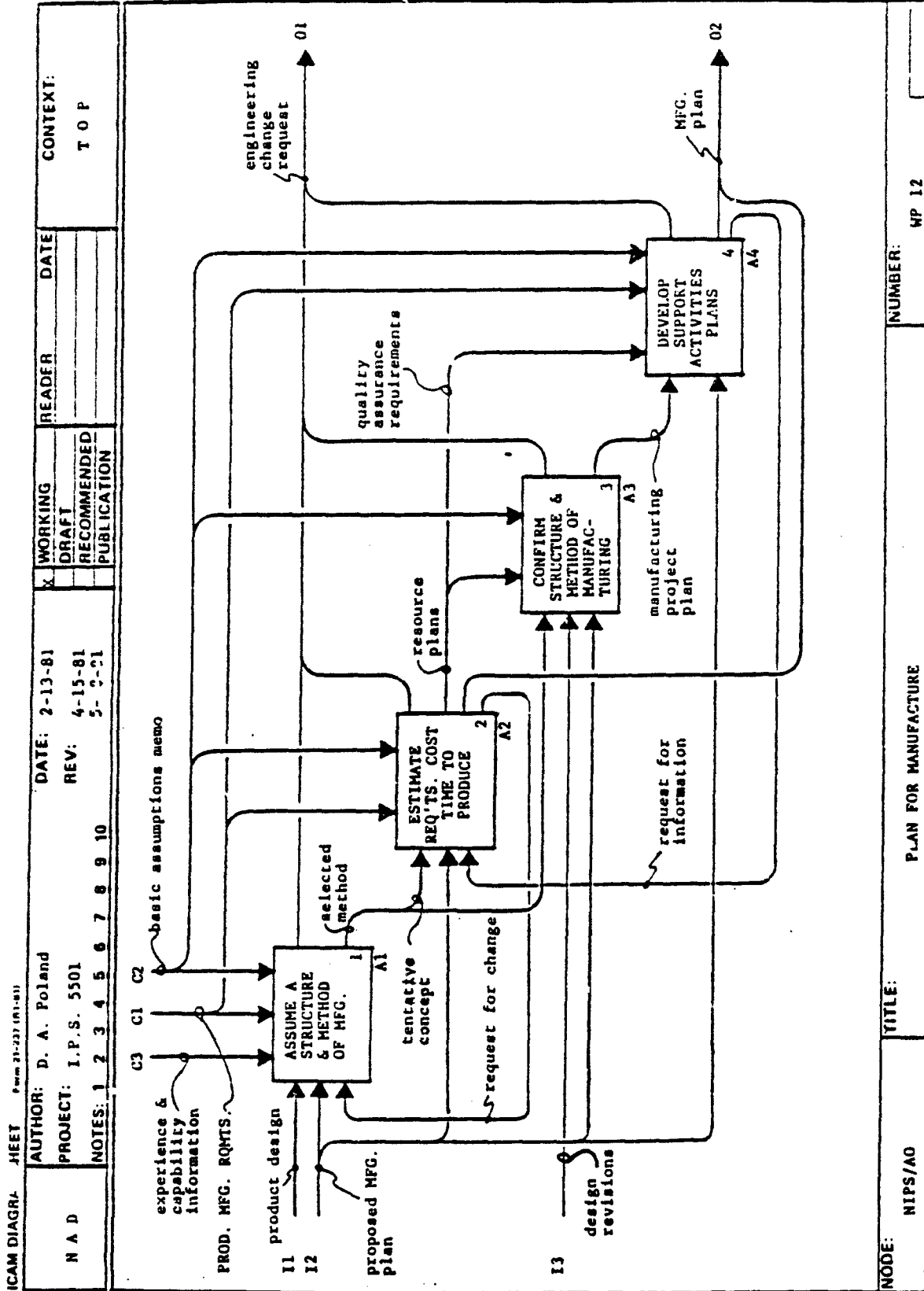


Figure 3-19. Plan for Manufacture

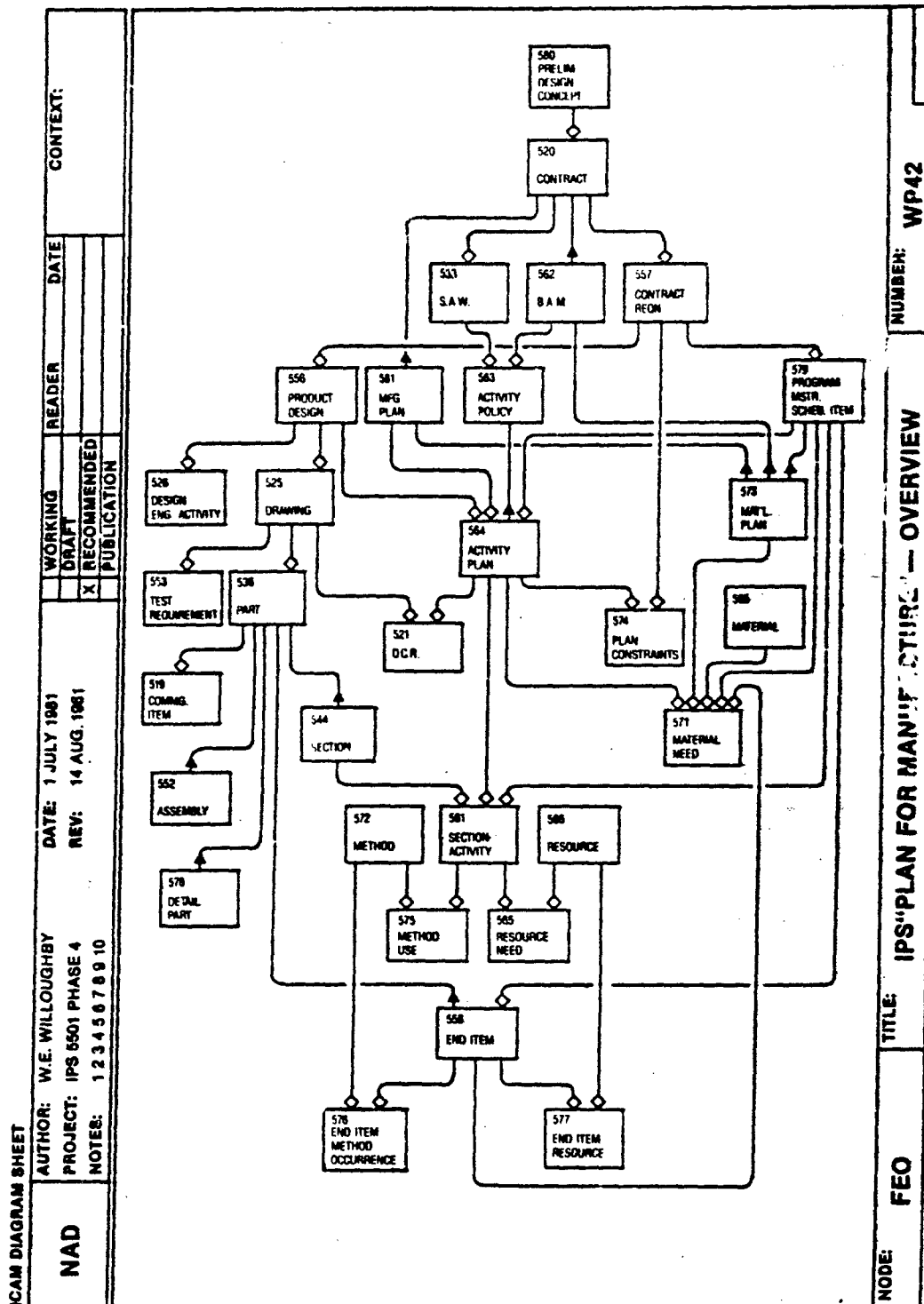


Figure 3-20. IPS "Plan for Manufacture" - Overview

The total development details related to PMS improvement concepts are included in the 15 major technologies contained in the third IPS interim Report (ITR550150003U).

3.4.6 Task 4, Subtask 6: Review State of the Art for PMS

3.4.6.1 PMS State-of-the-Art Survey

Accomplishments

The state-of-the-art process for PMS was similar to MPS described in paragraph 3.2.6. The responses regarding Engineering Change Control and Historical Capability indicated a technology void in available software packages reviewed.

This input provided the information needed to design the IPS system. A complete copy of the survey questions is contained in the third IPS interim Report (ITR550150003U).

A state-of-the-art document was published with the total results of the survey for MPS, FPS, and PMS. The document number is SAR550150000, and it is available in the ICAM library.

3.5 TASK 5, SUBTASK 1: DEVELOP AND FORMULATE IPS DESIGN

3.5.1 IPS Design Plan

Accomplishments

A preliminary and detailed design plan was established for IPS. The plan made provision for analyzing the preliminary design results and modified the configuration as required to establish an IPS prototype system. The preliminary design included the development of a System Specification (SS) and System Design Specification (SDS) for the IPS prototype system.

The SS and SDS provided the basis for the IPS prototype detail design.

3.5.2 Task 5, Subtask 2: Establish Preliminary Design

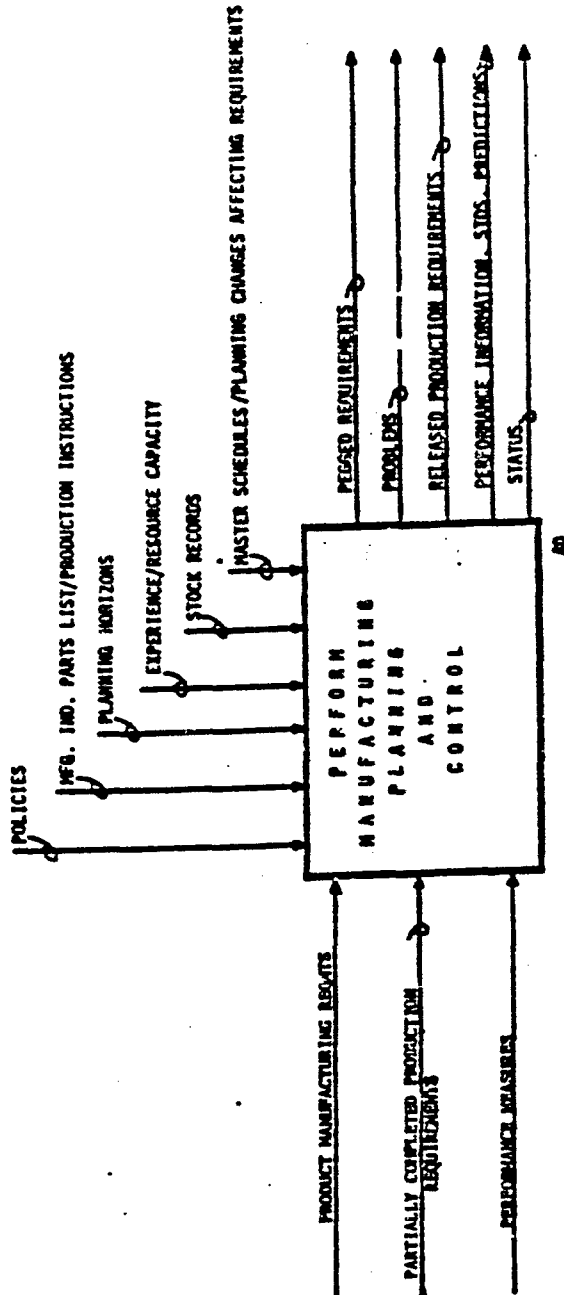
3.5.2.1 IPS Preliminary Design

Accomplishments

Preliminary design IDEF₀ models were constructed to identify the major IPS prototype modules and interfaces that would require development specifications. The top-level preliminary design "To-Be" IDEF₀ is contained in Figure 3-21, labeled RDN 10, Figure 3-22, labeled RDN 12, and Figure 3-23, labeled RDN 13. The complete preliminary design kit is IPS-OT-2 and is on file in the ICAM library.

To help understand the performance measures and dynamics of the IPS prototype system, a series of dynamics models was built using IDEF₂ methodology. The models were developed to address the areas of scheduling and loading of manufacturing resources. The models were constructed at General Dynamics and Rockwell International to help understand the mechanisms and dynamics of these technologies and to verify the performance measures required to build systems to accommodate actual production environments. A total of five models were built and are available in the ICAM library. The intention was to simulate the dynamics models on the Integrated Decision Support System (IDSS) for validation and evaluation.

USED AT:	AUTHOR: G.F. ROBERTS	DATE: 1/5/84	WORKING	READER	DATE	C TEXT:
	PROJECT: IPS PROGRAM 5501	REV:	DRAFT			
			RECOMMENDED			
			PUBLICATION			
NOTES: 1 2 3 4 5 6 7 8 9 10						



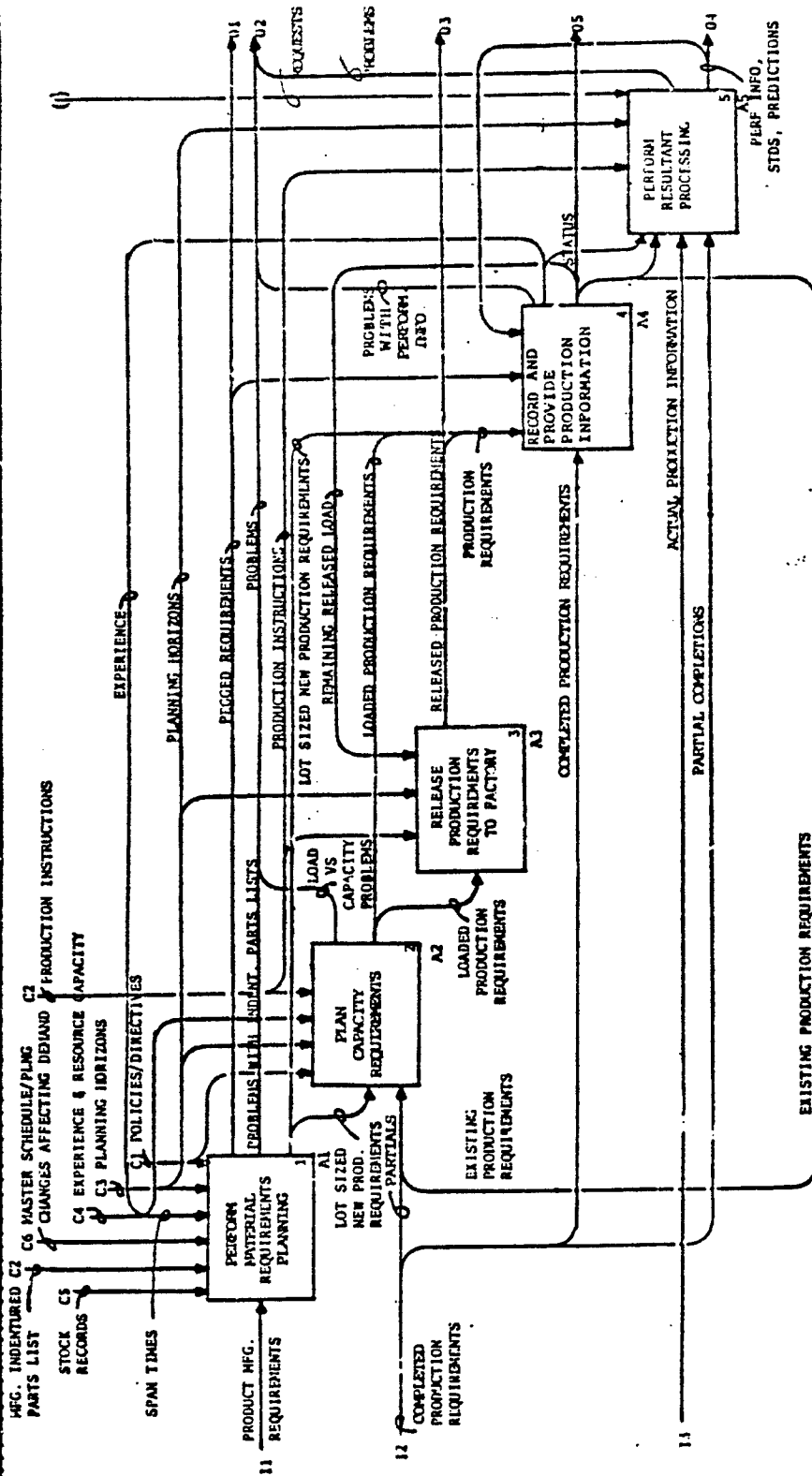
PURPOSE: THE PURPOSE IS TO ESTABLISH THE "TO BE" PERFORM MANUFACTURING PLANNING AND CONTROL.

VIEWPOINT: THE VIEWPOINT IS OF THE G.E. PROJECT PRIORITY 5501 (IPS) PROGRAM TEAM AND THE AEROSPACE FUNCTIONS RESPONSIBLE FOR PERFORMING MANUFACTURING PLANNING AND CONTROL.

NODE: PD/IPS/A-0	TITLE: "TO BE" PERFORM MANUFACTURING PLANNING AND CONTROL	NUMBER:	RPTD
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Figure 3-21. "To Be" Perform Manufacturing Planning and Control

USED AT:	AUTHOR: G. J. ROBERTS	DATE: 12-23-81	WORKING	READER	DATE	CONTEXT:
	PROJECT: IPS PROGRAM 5501	REV:	DRAFT			TOP
	NOTES: 1 2 3 4 5 6 7 8 9 10		RECOMMENDED			
			PUBLICATION			



NODE: PD/IPS/A0 TITLE: "TO BE" PERFORM MANUFACTURING PLANNING AND CONTROL NUMBER: RDN12

Figure 3-22. "To Be" Perform Manufacturing Planning and Control

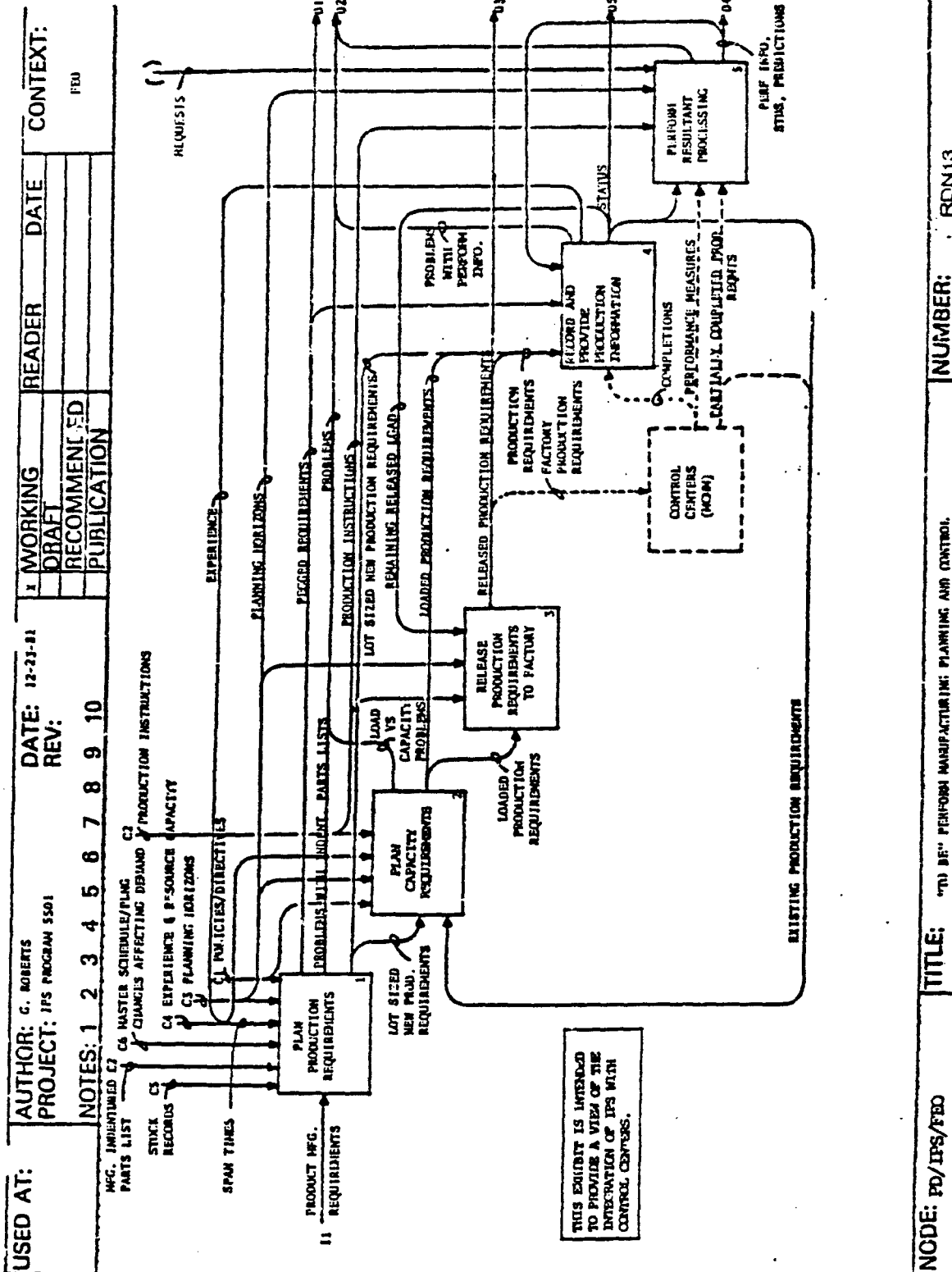


Figure 3-23. "To Be" Perform Manufacturing Planning and Control

The five models and their purposes are as follows:

<u>IDEF₁ Model Name</u>	<u>Purpose</u>
<ul style="list-style-type: none"> • Engineering Release/MRP List Reconciliation Process at General Dynamics 	<ul style="list-style-type: none"> • To illustrate the dynamic process behavior of the reconciliation of engineering releases with MRP lists in the current "As-Is" environment.
<ul style="list-style-type: none"> • Sheet Metal I/R Panel Manufacturing Cell at General Dynamics 	<ul style="list-style-type: none"> • To examine the effect of alternate manpower levels upon throughput of the IR panel manufacturing cell.
<ul style="list-style-type: none"> • Rockwell International's Engineering drawing Encoding Process 	<ul style="list-style-type: none"> • To translate Rockwell International's engineering drawing encoding process into an IDEF₂ model.
<ul style="list-style-type: none"> • Rockwell International's Order Release Process 	<ul style="list-style-type: none"> • To examine the effect of various production policies upon manpower loading in the release of engineering orders.
<ul style="list-style-type: none"> • The effect of Lot Sizing Policies and Multi-Year Aircraft buys upon shop floor labor and inventory costs at Rockwell International 	<ul style="list-style-type: none"> • To illustrate the potential for cost savings because of various lot sizing policies and multi-year aircraft buys.

3.5.2.2 Simulation Problems

Problems Encountered

The early product of IDSS was unable to support the simulation requirements necessary to process the dynamics models built.

3.5.2.3 Simulation Solution

Solution/Approach to Problem

Operation Flow Diagrams (OFD) were built by simulation analysts and manufacturing scheduling and planning experts who analyzed the dynamics through the modeling process and recommended performance measures, including response time, volume of data, accuracy etc. for the IPS prototype design.

3.5.2.4 IPS System Specification

Accomplishments

A System Specification (SS) was developed and refined for the IPS prototype system. This document detailed the requirements contained in the Systems Requirement Document (SRD). The functional requirements of the system were prioritized based on estimated benefits. Technology voids were enumerated for each of the following requirements:

- *Level Loading*

The major technology voids associated with level loading involve software needed to provide timely feedback regarding existing resource load status, and the capability to combine information about factory load with planned load not yet released to the factory. Software voids between the planning systems above the factory and control systems within the factory make it impossible to provide automatic interfaces. Available software capable of performing level loading have not been proven for large volumes of parts, do not provide dynamic queue-size determination, and cannot dynamically dispose of the inevitable need for load changes.

- *Effective Control of Capacity and Resources*

The technology void in effective control of capacity and resources is the lack of capability to obtain feedback and status that would measure the impact of a schedule on resources prior to a release to the factory. In addition, software capability to automatically evaluate the factory's capacity to fulfill a production schedule, automatically reschedule released orders, and provide new work packages is not available.

- *Experience and Capability (E&C)*

The major void in state-of-the-art software is the inability to interface the sources of status, performance information, and problems as feedback to higher-level systems for use in effective planning and control. The specific technology voids include structures for classification of information, standardization of information formats between the hierarchical structures of planning and control authority and responsibility, and software systems that provide the interfaces necessary for E&C information flow from its source to the using functions.

- *Control Concepts*

The technology void in the area of control concepts indicated improved accuracy for production requirements must be created for release to the factory. This requires a means of converting higher-level schedules to requirements for sub-assemblies and fabricated parts. An evaluation must be made of the probability that sufficient capacity exists to accomplish the load on the factory. An orderly means of optimally releasing work to the factory is required to assure that sufficient work has been released, but not so much as to allow manipulation within the factory that might result in excess buildup of inventory and not meeting predetermined required dates. Integration through common information reference and timely feedback is necessary to tie together the hierarchy of planning and control. This is essential to providing timely feedback from the factory as to how the load is (or is not) being achieved.

The SS outlined the functions, interfaces and data requirements for building an IPS prototype system. The SS is available as document number SS550150000, on file at the ICAM library.

3.5.2.5 IPS Systems Design Specification

Accomplishments

A System Design Specification was developed further refining the requirements presented in the System Requirements Document and the SS for the "To-Be" prototype system.

The mission of the "To-Be" system was to develop a Production Planning and Control System (PP&CS) that would have the ability to interact both internally between the functional areas and externally to those systems with which it was expected to interface. This would include the utilization of common data between the related systems (PP&CS modules and related external interfaces).

To further identify the requirements of the prototype system, a breakdown of individual configuration items (CIs) was developed. The CIs to satisfy the system requirements were as follows:

1. *Manufacturing Parts List (PL) Control Module*

This module provides the capability to verify that parts lists exist for all master production schedule items to be processed.

2. *Gross Requirements Module*

This module extends gross requirements within effectivity (Configuration Control) from the master production schedule items.

3. *Adjustment Module*

This module provides adjustments to requirements quantities for process loss.

4. *Net Requirements Module*

This module converts gross requirements to net requirements in consideration of any available inventory and/or open orders.

5. *Lot Size Module*

This module produces lot sizes from net requirements according to predetermined policies.

6. *Capacity Profile Module*

This module explodes labor for loading and comparison to available capacity across the manufacturing planning horizon.

7. *Factory Order Release Module*

This module releases production requirements to the factory based on earliest start date and in consideration of the maximum amount of load to be maintained in the factory.

8. *Production Information Control Module*

This module receives, validates, and provides information used and/or created by the PP&CS system.

9. *Resultant Processing Module*

This module conditions performance information, provides performance measures, and projects future factory performance.

10. *Intra-System Communications Module*

This module controls the sequencing of the PP&CS system priorities and software steps. It provides the ability to pass intermediate information formats between the PP&CS system modules. It also provides data protection and recovery procedures to reinitiate job steps from pre-established recovery points.

11. *Inter-System Communications Module*

This module provides the ability to receive information such as the master production schedule and parts lists and stock balances from other systems. It also provides information such as factory order releases to other systems.

A process of grouping CIs was conducted to provide a modular approach to the system design effort. Figure 3-23, labeled RDN 13, was the final product of grouping CIs into system modules for further detail design.

After an extensive search and analysis of vendor-available packages and software, it was decided to buy an MRP module that would include the CIs 1-5. SDS detailed the modules that would be developed in detailed design to satisfy a PP&CS. These modules were identified as follows:

- CI6 - Perform Factory Loading
- CI7 - Release Production Requirements
- CI8 - Record and Provide Production Information
- CI9 - Perform Resultant Processing

CIs 10 and 11 were defined as links to interface within the PP&CS system and externally to outside system interfaces (such as the MCOMM shop floor control system). See Figure 3-24.

The SDS is available as document number SDS 550150001 on file in the ICAM library.

3.5.2.6 *PP&CS Development Specifications (DS)*

Accomplishments

A Development Specification (DS) was prepared for each CI to be designed. The DS described the user interface, functional requirements, information requirements, inputs, processing descriptions, and outputs for each CI.

To achieve the PP&CS detailed design, these specifications were constructed:

- CI-6 Perform Factory Loading
- CI-7 Release Production Requirements
- CI-8 Record and Provide Production Information
- CI-9 Perform Resultant Processing
- CI-11 Interface to External Functions

The following is a brief discussion of each specification:

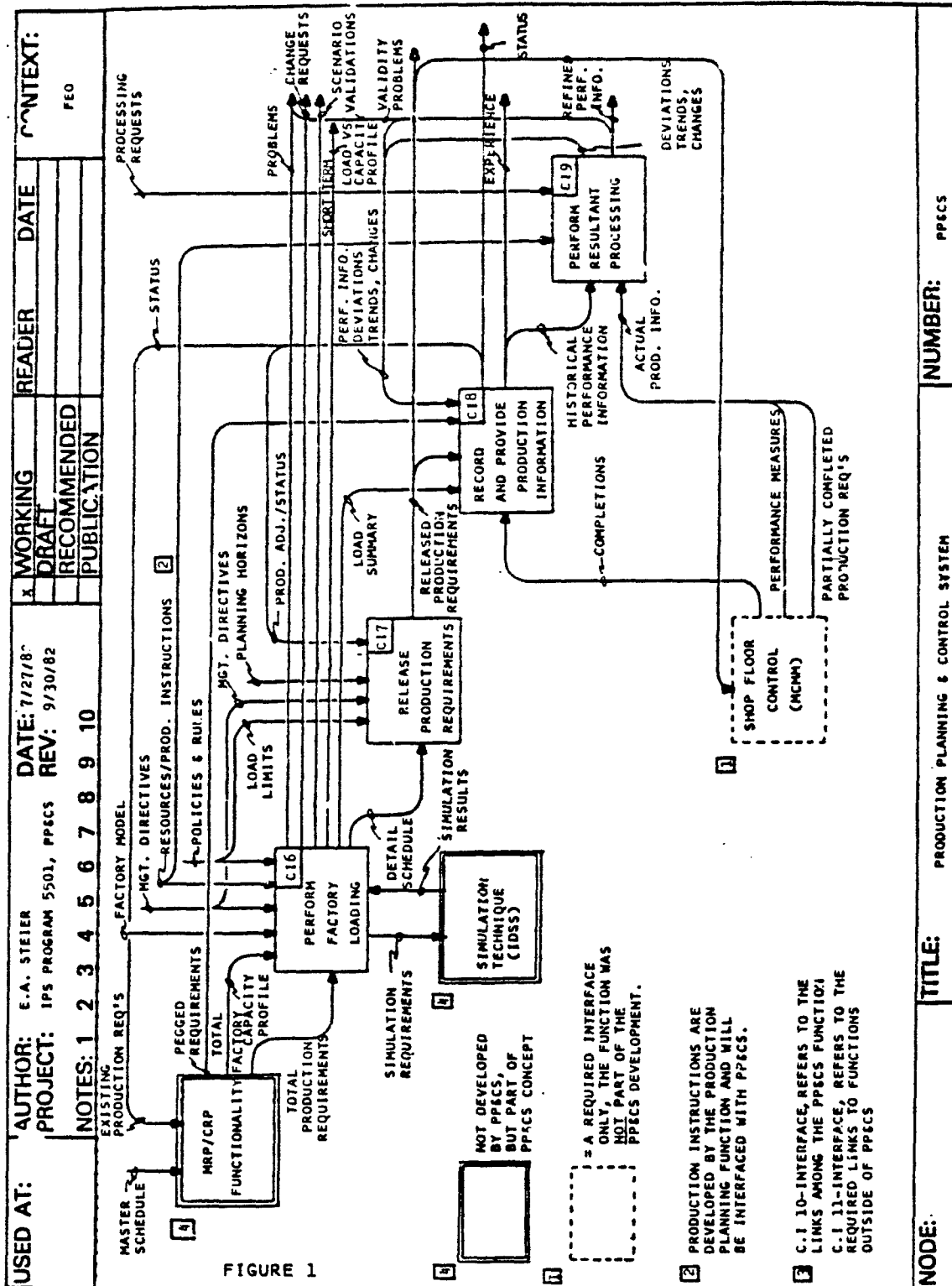


Figure 3-24. Production Planning and Control System

3.5.2.7 Factory Loading Development Specification

Accomplishments

The CI-6 Perform Factory Loading DS describes the detail sequence loading and balancing of the factory. This process is accomplished within limits of available capacity identified by the manufacturing planning function. This module is the heart of the prototype system.

Production requirements are compared to production instructions (process routings) to explode labor which will be used to load manufacturing resources.

Two attempts are made to validate the load within the required schedule: long term and short term. The initial pass is for a longer horizon that summarizes and balances the load for the factory by resource within periods. The purpose of the longer horizon is to solve the capacity problem through leveling and balancing the load. Assuming a successful summary loading, a shorter horizon may be selected for detail sequence loading and balancing at the process level by resource.

It is not necessary to run long-term loading prior to running short-term sequence loading and balancing.

The long and short term loading techniques are independent algorithms. The major functions that were developed in detailed design for eventual construction of code for Factory Loading are as follows:

- Long-Term Loading (LTL)
- Long-Term Balancing (LTB)
- Short-Term Loading (STL)
- Short-Term Balancing (STB)
- Simulation Capability (Schedule Evaluator)

The CI-6 Factory Load development specification is available as document DS5501502061 on file in the ICAM library.

3.5.2.8 Release Production Requirements Development Specification

Accomplishments

A Development Specification for the preliminary design was completed for CI-7 Release Production Requirements. The objective of the Release Production Requirements functionality is to effectively meter the flow of work to the shop floor.

Initial functions accept the detail schedule as input and estimate an expected release date for each production requirement included in the detail schedule. The expected release date is determined by taking into consideration the current released load and load restrictions (i.e., upper and lower limits on the amount of work that may be released) for each resource defined within the factory hierarchy. A release schedule, displaying release dates for each production requirement, is produced and may be displayed by the user.

This CI also identified potential adjustments to required quantities of parts for production requirements. For example, shortages because of poor yield or excesses due to lot sizing may be recorded in the data base as production requirements are completed on the shop floor. A

report is generated that identifies all production requirements for which quantity adjustments may be desired. After production requirements eligible for quantity adjustment have been identified, the user is given the opportunity to actually modify required quantities.

The user is also given the ability to display the status of released load for all centers, cells, stations, and processes defined within the factory hierarchy. Specifically, a conventional formatted display or, optionally, a bar chart display conveys various items of load information including the released load, released load upper and lower limits, and the dispatched load.

The user, after having assessed the displayed load information, may then select one or more resources to which production requirements will be released. Production requirements are always released to centers within the factory, but the user is given the option of identifying underloaded resources, perhaps at a lower level than the center level, for which production requirements are to be released. The user is also given the ability to specify the amount of work to be released to each of the selected resources.

After having selected resources, the user is then given the option of analyzing the impact of the impending release on all resources. That is, the impact of having specified the amount of work about to be released to the selected resources is determined without actually releasing production requirements. A production planner is thereby able to more accurately predict overloads, bottlenecks, underloads, etc. and, therefore, is better able to identify the need for overtime, subcontracting, or reassignment. Production requirements are then actually released for the selected resources to the shop floor.

The major functions were detailed in the DS are as follows:

- Set Release Parameters
- Load Production Requirements
- Estimate Release Dates
- Display Release Schedule
- Identify Quantity Adjustments
- Adjust Production Requirements
- Display Load Status
- Select Resources for Release
- Analyze Release Impact
- Release Production Requirements for Selected Resources

The DS for CI-7 Release Production Requirements included the functionality, inputs, user interface, data requirements, and outputs for the above-listed functions.

Because of the site-specific requirements of a release module in the different aerospace companies a decision was made by the Air Force and General Electric to prepare detailed software design information for this module and not to proceed with implementation.

The DS for CI-7 Release Production Requirements, DS550153071, is available in the ICAM library.

3.5.2.9 Record and Provide Production Information DS

Accomplishments

The CI-8 Record and Provide Production Information DS was developed. It described the functional information data requirements, inputs, processing rules and algorithms, user interface, and outputs.

The primary objective of this CI is to record and provide production information. The recording of information pertains to data that is required to support factory loading, release of production requirements, and resultant processing. This includes information which is not available through interfacing systems. Additionally, the initialization and maintenance of this information does not constitute a mainstream function of any of these system modules. This CI also addresses providing manufacturing management with information to support decision making. Again, the provision of this information does not fall within the mainstream activities of the CIs listed above.

This function receives factory environment information in addition to planned, actual, and performance information. Factory information is obtained from the organization responsible for the factory configuration. Planned information is obtained through the planning functions. Actual production information is obtained from the factory. Performance information is obtained from Perform Resultant Processing CI-9.

All information is validated for correct format and content. If valid, the information is stored and retrieved upon request. Invalid inputs are appropriately handled through error processing routines. Production requirements are provided and status information is reported.

The major functions that were described in detail were as follows:

- Define Factory Levels
- Define Factory Resource
- Display Factory Hierarchy
- Define Machine Type
- Delete Factory Resource
- Delete Machine Type
- Define Capacity
- Display Capacity
- Maintain Shop Calendar Parameters
- Maintain Shop Calendar
- Display Shop Calendar
- Define Move Times
- Adjust Load Parameters

The preliminary design of the above functions were provided to the detailed design Task 5, Subtask 3.

The DS for CI-8 Record and Provide Production Information, DS550154081, is available in the ICAM library.

3.5.2.10 Perform Resultant Processing DS

Accomplishments

The CI-9 Perform Resultant Processing DS was completed for the preliminary design phase.

The primary objective of this CI is to accumulate actual performance data from the factory, establish performance characteristics, measure those characteristics against plan and historical performance, and report trends and deviations.

Initially, factory feedback data is validity-checked and then various performance measures are calculated to characterize the performance. The measures used emphasize values normalized against plan values that can then be used for comparison across jobs, machines, and time. The performance measures calculated are summarized across jobs and over time to obtain average performance for part numbers and operations, machines for all parts, and sub-operation plans across jobs and in the manufacturing hierarchy over time. The performance of the factory is summarized as a function of time to provide periodic information by day, week, month, quarter, and year, as appropriate. Longer-term trend measures are calculated corresponding to each time period. The operation plan, machine, and factory performance are analyzed to determine significant trends and changes. A general statistical analysis capability, IDSS, is provided to allow the historical data to be accessed and analyzed. Finally, a capability is provided to allow the user to recommend changes to the performance standards that will be used in the operation plans.

The major functions described in the Perform Resultant Processing DS are as follows:

- Validity Check Feedback Information
- Calculate Job-Related Measures
- Calculate Machine-Related Measures
- Calculate Move/Queue-Related Measures
- Update Historical Performance
- Summarize Performance Information
- Summarize Subplan Performance
- Obtain and Summarize Periodic Information
- Analyze Performance

The Perform Resultant Processing DS detailed the functional and information data requirements, inputs, processing rules and algorithms, and outputs for the above functions.

The CI-9 Resultant Processing, DS 550152091, is available in the ICAM library.

3.5.2.11 PP&CS Interface DS

Accomplishments

A CI-11 Interface DS was developed, describing the functional and information data requirements, inputs, processing rules and algorithms, user interface. and outputs.

The primary objective of this DS was to document the major functions responsible for interfacing to existing manufacturing application systems that are external to PP&CS.

The CI-11 Interface, DS 550156111, is available in the ICAM library.

3.5.2.12 PP&CS Quality Assurance (QAP) Plan

Accomplishments

A Quality Assurance Plan was developed to formally identify QA provisions to be carried out for the development of PP&CS software.

The plan was prepared in accordance with QA requirements outlined in Mil Spec MIL-5-52779A, entitled, "Software Quality Assurance Program Requirements."

The plan described provisions addressing specific QA requirements for PP&CS software development. In particular, QA strategies for each of the following requirements were described:

- Tools, Techniques, and Methodologies
- Computer Program Design
- Documentation
- Computer Program Library Controls
- Reviews and Audits
- Configuration Management
- Testing
- Corrective Action

The quality assurance plan, QAP550150001, is available in the ICAM library.

3.5.2.13 PP&CS System Test Plan

Accomplishments

A System Test Plan was developed for PP&CS to provide an approach for monitoring and controlling the testing and integration of PP&CS software.

It was planned that the testing of PP&CS be broken down into four major levels that would require specific tests or series of tests to ensure that each level met the requirements and functional specifications that were previously developed. The following levels of test were established:

<u>Levels</u>	<u>Type of Testing</u>
System	System Test and Validation
Configuration	Integration Test
Transactions	Transaction Test
Programs	Unit Test

The complete System Test Plan, STP550150001, is available in the ICAM library.

3.5.3 Task 5, Subtask 3: Establish Detailed Design

Accomplishments

This phase of the project resulted in the development of four product specifications constructed in accordance with ICAM documentation standards. These specifications document PP&CS detailed design accomplishments in the following functional areas:

1. Perform Factory Loading -- (PS 550152061)
2. Record and Provide Production Information -- (PS 550154081)
3. Release Production Requirements -- (PS 550153071)
4. Perform Resultant Processing -- (PS 550152091)

The PP&CS detailed design effort adhered to software engineering design guidelines and conventions identified for the IISS test bed developed under ICAM Project Priority 6201M. A summary of detailed design accomplishments in each of the above functional areas is presented below.

3.5.3.1 Perform Factory Loading (PS 550152061)

Accomplishments

A number of transactions were designed in support of the Perform Factory Loading function of PP&CS. Specifically, detailed design documentation for the following transactions was developed.

1. Prepare MRP Input

Before any of the Factory Loading functions concerned with the analysis of manufacturing load versus capacity can be executed, it is first necessary to properly initialize the PP&CS data base with planning information generated from an MRP system. This information takes the form of new production requirements (i.e., net requirements), cancellations to (i.e., deletions of) existing production requirements, and modifications to existing production requirements. Modifications to production requirements take the form of:

- quantity changes
- due date changes
- earliest start date changes
- priority changes

Additions, cancellations, and modifications are communicated to PP&CS via an interface function responsible for retrieving appropriate information from the data base of the commer-

cial MRP system. Production requirement information communicated via this interface function will then be accessed by the PREPARE MRP INPUT function, primarily responsible for initializing and modifying the PP&CS data base.

This function was designed to filter the data by detecting production requirements identifying parts that have not yet been defined within the PP&CS data base and parts for which no process planning information has yet been defined. Appropriate error reports can be generated after invoking the data prep function which also executes as a background task.

2. Long-term Loading (LTL)

The primary objectives of the LTL function are:

- To provide the capacity planner with an understanding of underloaded and overloaded resources at different levels of the factory organizational hierarchy, e.g., departments, centers, cells, etc. Such information then serves as input to the Long-Term Balancing (LTB) function (described subsequently), whose primary responsibility is to balance or smooth the overloaded planning periods.
- To provide a generic system with respect to the factory hierarchy that could be used in any manufacturing environment involved with discrete parts production (i.e., job shop environment) and/or batch assembly.

A data flow diagram highlighting the major activities of the LTL function is illustrated in Figure 3-25.

The first activity is responsible for gathering appropriate user input, including:

- load method (options for forward or backward loading)
- horizon start and end dates
- planning period size (fiscal weeks, months, quarters or years)
- resources for which operations are to be loaded

Samples of screen formats for the LTL user interface are illustrated in Figures 3-26 through 3-30. In particular, the screens shown perform the following:

Figure 3-26 Prompts user to select method by which loading is to be performed.

Figure 3-27 Enables user to specify the planning horizon and period size.

Figures 3-28, 3-29 and 3-30 illustrate screens enabling the user to restrict the loading function to specific portions of the factory hierarchy environment.

The second activity is responsible for determining which of the production requirements are eligible for loading (based on horizon start and end dates identified by the user) and distributing the eligible production requirements to separate files to facilitate processing by the subsequent activity.

The third activity is multi-tasked and is primarily responsible for determining which operations, referred to as "load units (LU)," of the eligible production requirements are eligible to be loaded. Operations falling prior to the horizon start date or beyond the horizon end date will not be included in the load. Each task performing this activity generates a separate file identifying eligible operations and the planning period(s) to which it must be associated.

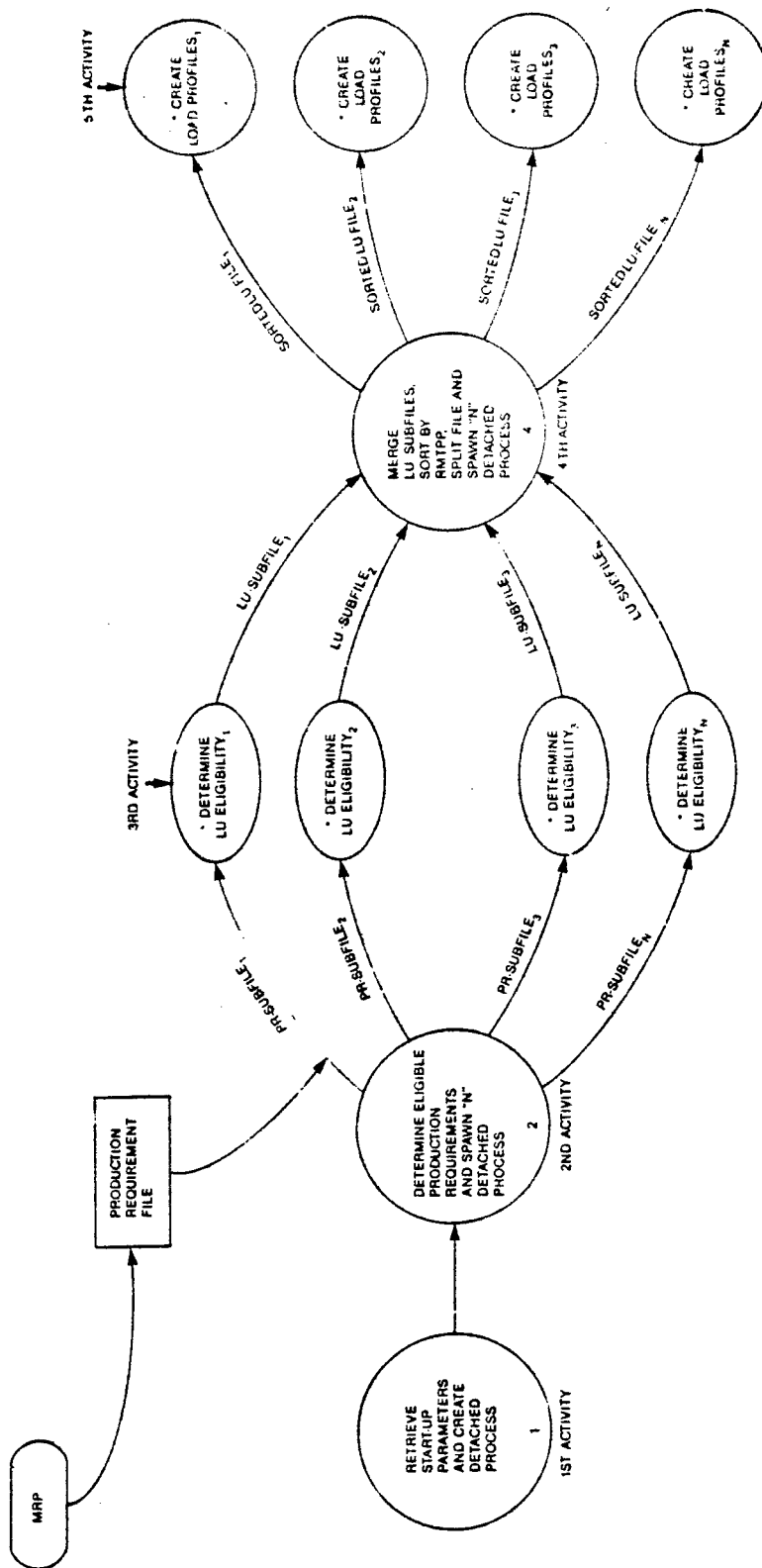


Figure 3-25. Data Flow Diagram for Long-Term Loading

MULTIPLE CONCURRENT TASKS

USER INTERFACE

PERFORM LOAD ANALYSIS

SPECIFY LOADING METHOD

BACKWARD LOAD:

1. FROM REQUIRED DATE
2. FROM EARLIEST COMPLETION DATE

FORWARD LOAD:

3. FROM EARLIEST START DRIVE
4. FROM LATEST START DATE

ENTER SELECTION: _

Figure 3-26. Long-Term Loading

USER INTERFACE

PERFORM LOAD ANALYSIS

LOAD METHOD: XXXXXXXXXXXXXXXXXXXXX

SPECIFY PLANNING HORIZON:

START DATE: 09/07/1983
END DATE: 99/99/9999

SPECIFY PLANNING PERIOD SIZE:

1. FISCAL WEEKS
2. FISCAL MONTHS
3. FISCAL QUARTERS
4. FISCAL YEARS

ENTER SELECTION: _

Figure 3-27. Long-Term Loading

USER INTERFACE

PERFORM LOAD ANALYSIS

LOAD METHOD: XXXXXXXXXXXXXXXXXXXX

HORIZON START DATE: 99/99/9999

HORIZON END DATE: 99/99/99

PLANNING PERIOD SIZE: XXXXXXXXX

SPECIFY FORM OF LOADING:

1. LOAD ALL PRODUCTION REQUIREMENTS
2. LOAD AT A SPECIFIC LEVEL

ENTER SELECTION: _

Figure 3-28. Long-Term Loading

USER INTERFACE

PERFORM LOAD ANALYSIS

LOAD METHOD: XXXXXXXXXXXXX .XXX

HORIZON START DATE: 99/99/9999

HORIZON END DATE: 99/99/99

PLANNING PERIOD SIZE: XXXXXXXXX

LEVEL: XXXXXXXXXXXXX

SPECIFY RESOURCES FOR LOAD ANALYSIS:

SELECTION(S)

```

- XXXXXXXX
- XXXXXXXX
- XXXXXXXX
- XXXXXXXX
- XXXXXXXX
- XXXXXXXX
- XXXXXXXX
- XXXXXXXX
- XXXXXXXX
- XXXXXXXX
- XXXXXXXX
- XXXXXXXX

```

Figure 3-29. Long-Term Loading

USER INTERFACE

PERFORM LOAD ANALYSIS

LOAD METHOD: XXXXXXXXXXXXXXXXXXXX

HORIZON START DATE: 99/99/9999

HORIZON END DATE: 99/99/99

PLANNING PERIOD SIZE: XXXXXXXXX

SPECIFY LEVEL FOR LOAD ANALYSIS:

1. FACTORY
2. CENTER
3. CELL
4. STATION

ENTER SELECTION: _

Figure 3-30. Long-Term Loading

The fourth activity merges the files produced by the previous activity. The merged file is then sorted by Resources, Machine Types (RMT), and Planning Periods, and split into a number of subfiles again to facilitate processing to be performed by the following task.

The fifth activity is also multi-tasked and performs the actual loading of the PP&CS database, i.e., the association or connection of load units to planning periods and the accumulation of load versus capacity by resource.

3. Long-term Balancing (LTB)

The objective of LTB is to determine which planning periods are overloaded as a result of LTL and to balance the load by moving the load from overloaded periods to underloaded periods. Data flow diagrams highlighting major activities incorporated within the design of LTB are illustrated in Figures 3-31 and 3-32. Figure 3-32 represents an explosion of the Perform Attempts activity shown in Figure 3-31.

The first activity in Figure 3-31 retrieves required input from the user. Specifically, it prompts the user for information similar to that described for LTL above.

The second activity performs a modified version of LTL which is responsible for loading the entire factory. LTL, as described in the previous subsection, performs an "analysis" function enabling the user to determine problem periods without incurring unnecessary database overhead. In other words, via the LTL transaction it is possible for the user to limit the scope of the function to a subset of critical or "bottleneck" resources that perhaps have historically been characterized with capacity problems for a particular manufacturing environment. The comparable activity in LTB loads all factory resources and in effect prepares the data base for the ensuing balancing activities.

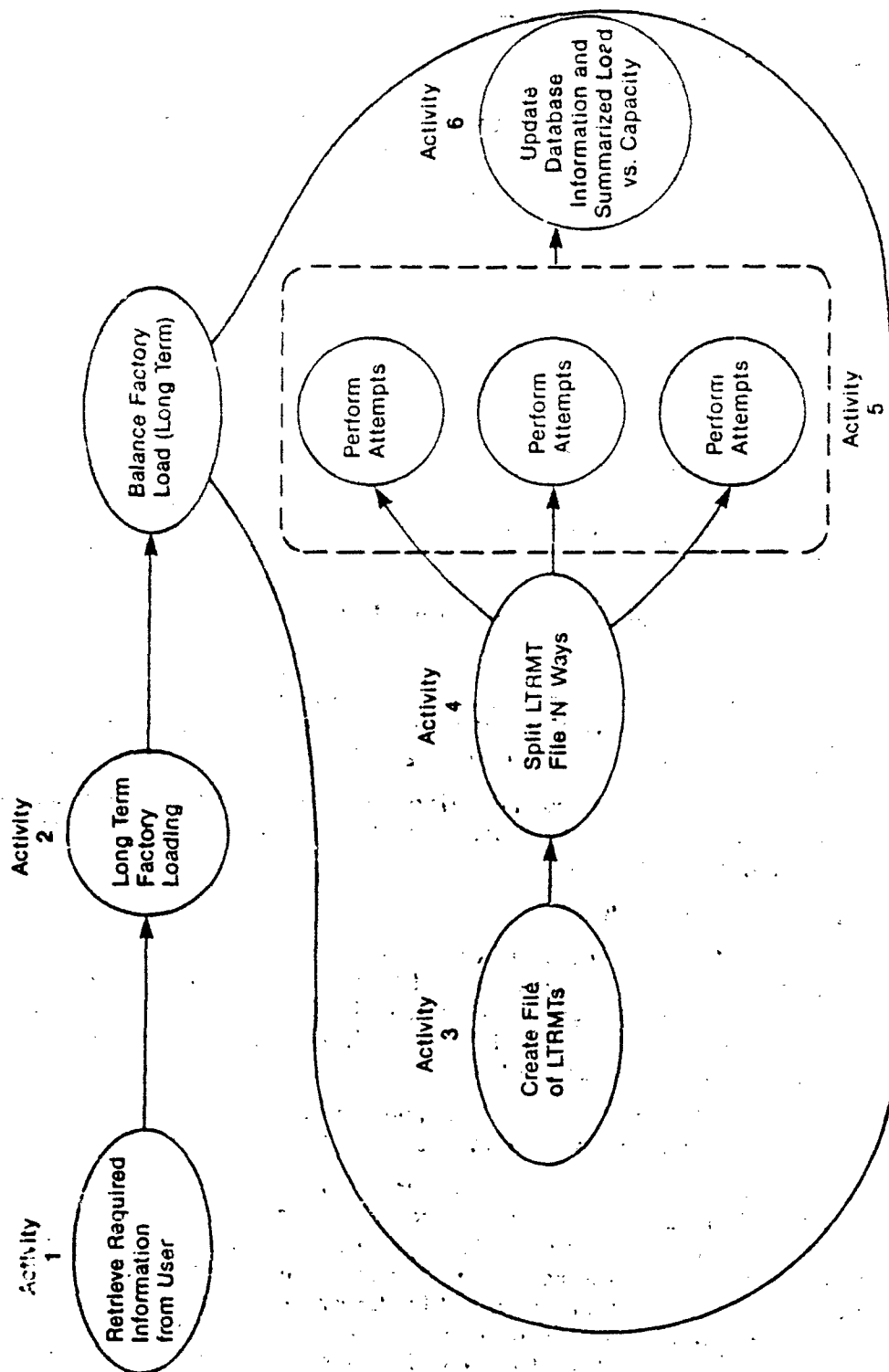


Figure 3-31. Long-Term Factory Load Balancing

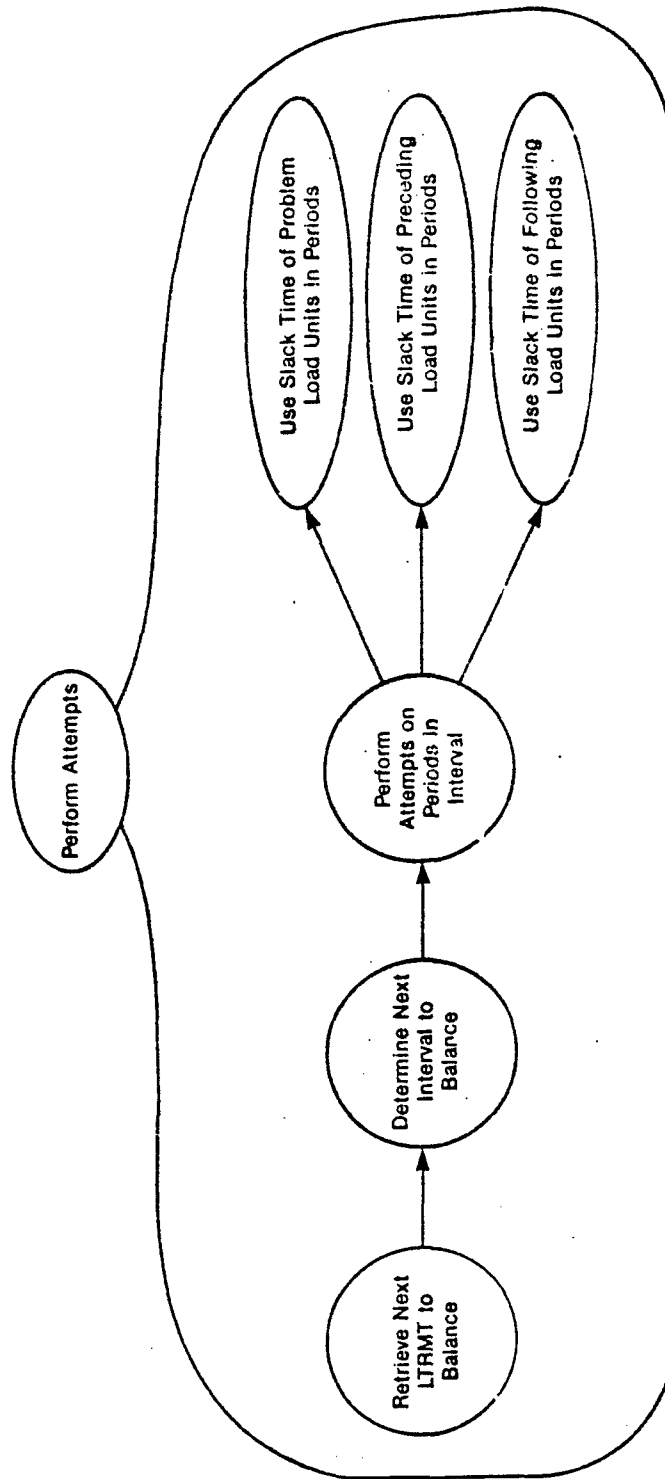


Figure 3-32. Long-Term Factory Load Balancing

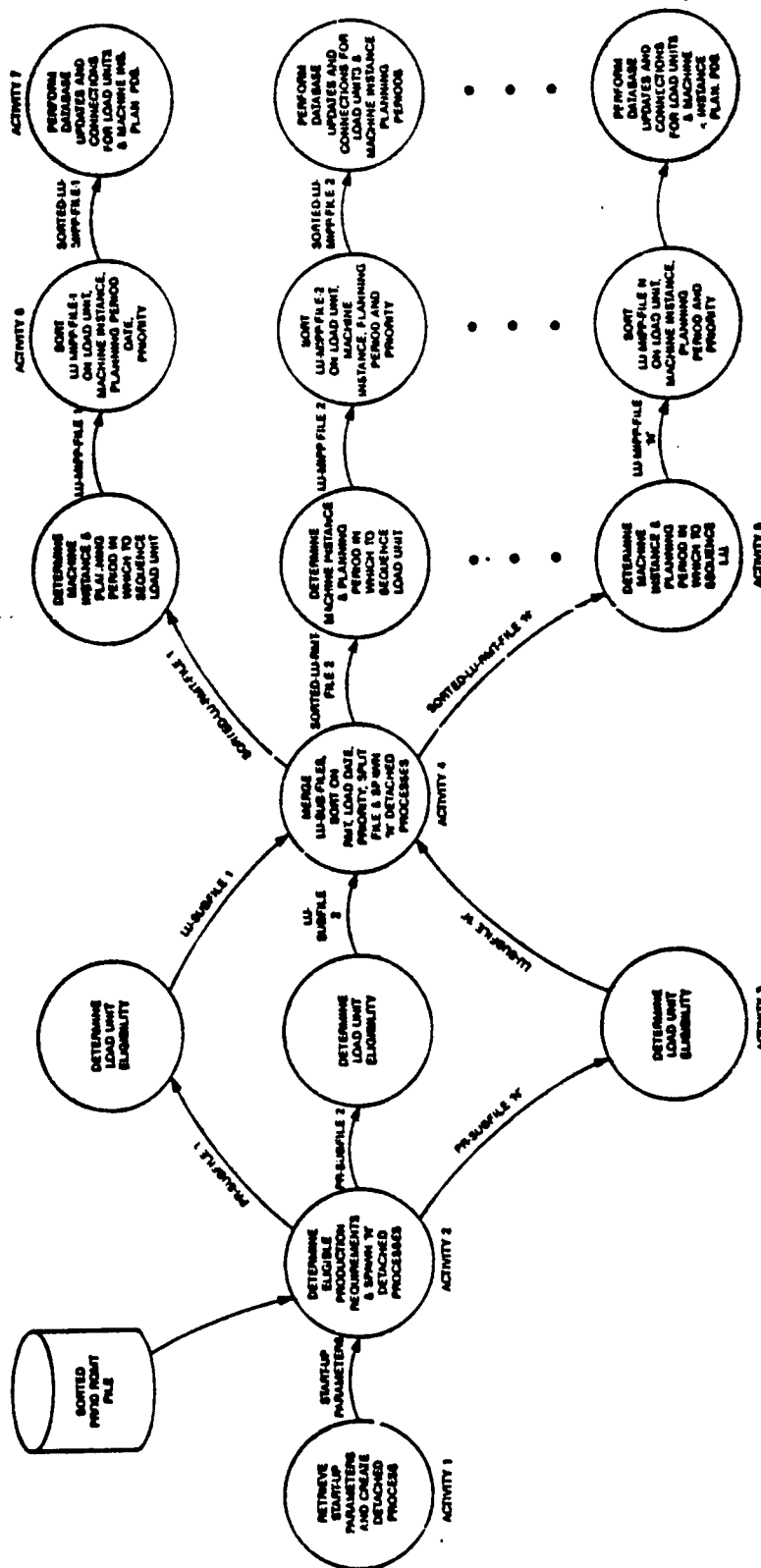


Figure 3-33. Short-Term Loading Major Activities

The third activity in Figure 3-31 is the activity responsible for initiating the actual balancing function. Specifically, this activity identifies all resource machine type (RMT) combinations that were determined (by the previous activity) to be overloaded. Activity 4 then splits this group of resource machine type combinations into subsets according to high-level manufacturing centers. This facilitates multi-tasking to be performed by the perform attempts, Activity 5, exploded in Figure 3-32..

The last bubble of Figure 3-31 Activity 6 is responsible for summarizing load versus capacity information for the entire factory hierarchy.

4. Short-term Loading (STL)

STL, much like LTL, also provides the capacity planner with an understanding of underloads and overloads of capacity. LTL, however deals with higher-level organizations (see Figure 3-40), i.e., "resources" within the factory hierarchy and larger period sizes, e.g., weeks, months, or quarters. Unlike LTL, STL places load units onto specific machines for a specific day in priority sequence and is usually concerned with a shorter near-term horizon (two to eight weeks). Note also that STL is more accurate than LTL within this horizon because it deals with specific machine capacity rather than a more general aggregate of "machine type family" capacity utilized by LTL. Other differences between short-term and long-term loading are highlighted in Figure 3-34. Data flow diagrams highlighting major activities of STL are illustrated in Figure 3-33. Activities 1 through 4 are similar to those carried out by LTL in Figure 3-31. Activities 5 through 7, however, involve the selection of specific machines, a determination of specific days on which operations are to be performed, and the necessary database updates.

5. Short-term Balancing (STB)

The primary objective of STB is to balance overloads detected as a result of short-term loading. Major differences between STB and LTB are summarized in Figure 3-35.

6. Define Factory Capacity

Before any of the long-term or short-term capacity planning transactions are executed, it is first necessary to specify the capacity of the individual machines within the manufacturing environment. This transaction enables the capacity planner to interactively define capacity for one or more machines. The design of this transaction enables the definition of capacity by production control personnel at any level in the factory organization for various planning horizons. For example:

- A planner interested in projecting long-range load versus capacity may use this transaction to define SINGLE SHIFT capacity for ALL machines in the factory for the next two years. OR
- A planner interested in solving medium-range capacity problems may use this transaction to increase capacity for certain bottleneck work centers (e.g., "DEPT5 DRILLS") for the next few months. OR
- A shop foreman may use this transaction to define overtime capacity for the upcoming weekend for a specific machine (e.g., "DRILL25").

7. Display Capacity

This transaction was designed for the purpose of enabling a capacity planner to graphically display the summarized capacity (as defined via the previous transaction) for a specific

LONG TERM	SHORT TERM
2 - 6 MONTHS	2 - 8 WEEKS
LOAD UNITS ARE PLACED IN A PERIOD IN NO SPECIFIC ORDER	LOAD UNITS ARE SEQUENCED IN THE ORDER IN WHICH THEY ARE TO BE PERFORMED ON A MACHINE
LOAD TO RESOURCE MACHINE TYPES	LOAD TO INDIVIDUAL MACHINES
PERIOD SIZE IS VARIABLE	PERIOD SIZE IS FIXED AT DAYS
DOES NOT IDENTIFY OVERLOADS WHILE LOADING; THIS IS LEFT FOR BALANCING	PROBLEM LOAD UNITS ARE FLAGGED WHILE LOADING; BALANCING DEALS WITH THESE PROBLEMS

Figure 3-34. Differences Between Long-Term and Short-Term Loading

LONG TERM	SHORT TERM
DETERMINES INTERVALS TO BE SOLVED AND IS ALLOWED TO MOVE ALL LOAD UNITS WITHIN A PROBLEM PERIOD	PROBLEM LOAD UNITS ARE FLAGGED WHILE LOADING; THESE ARE THE ONLY LOAD UNITS WHICH MAY BE MOVED
USES SLACK TIME SLIDING AND FLOW TIME COMPRESSION	ALSO USES ALTERNATE OPERATIONS

Figure 3-35. Differences Between Long-Term and Short-Term Balancing

resource or resource machine type combination ((e.g., "CENTER1 DRILLS") within the factory hierarchy. A sample bar chart display resulting from the execution of this transaction is included in Figure 3-36 (Bar Chart for Displaying Capacity).

8. Display Load Versus Capacity

This transaction enables a capacity planner to graphically display the results of LTL or LTB. Its design provides for the display of load versus capacity for a specific resource or resource machine type combination defined within the factory hierarchy. The load versus capacity display may be specified for weeks, months, or quarterly periods. A sample bar chart display resulting from the execution of this transaction is included in Figure 3-37 (Bar Chart Display for Load vs. Capacity).

9. Display Detailed Capacity Versus Load Profile

This transaction enables a capacity planner to graphically display the results of STL or STB. Its design provides for the display of load versus capacity for a specific machine or process defined within the factory hierarchy. Load versus capacity is displayed in terms of days.

10. Display Load/Balancing Results

This transaction provides the user with a hard-copy report detailing the load for a specified range of planning periods. This report can be generated after the execution of LTL or LTB and summarizes load in terms of order numbers, part numbers, specific operations comprising the load, and effective load hours (i.e., run time and setup time).

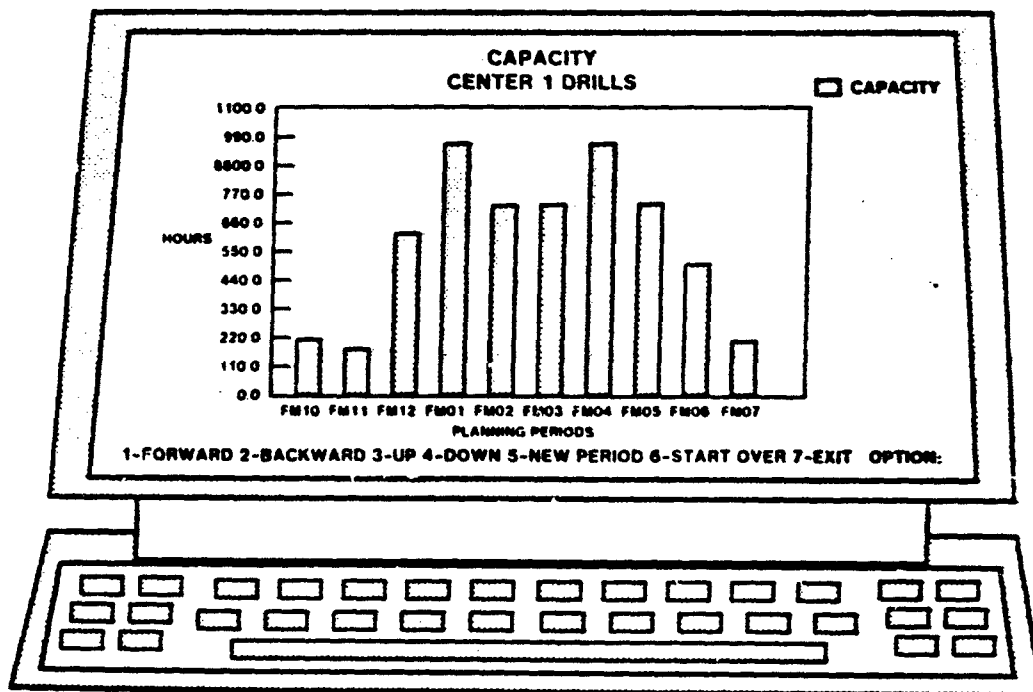


Figure 3-36. Bar Chart for Displaying Capacity

11. Display Detail Load Schedule

This transaction provides the user with a hard-copy report detailing schedule information generated from the execution of STB. This report differs from that of the previously described LTL/LTB report in that the priority information along with the specific days on which jobs are to be worked is included.

12. Extract Data for Simulation

A data extraction transaction was also developed to provide an interface between PP&CS and scheduling simulation software developed by Pritsker & Associates under Project Priority 8205 (IDSS Build 1). This simulation software provides decision support to the users of PP&CS Factory Loading software regarding short-term loading and short-term balancing parameters and the feasibility and risk of the schedules resulting from STB.

The primary tasks of the simulation are to 1) Independently verify the schedule that results from PP&CS STL and STB functions and to 2) Provide feedback about queue time parameters used in the process. The secondary but still important tasks are to provide feedback about PP&CS move time and slack time parameters and to provide information on resource utilization.

The first step in the simulation is to extract from the PP&CS data base schedule information generated by STB. The extraction is performed by the EXTRACT DATA FOR SIMULATION transaction. Using planned move times and effective load hours, the simulation

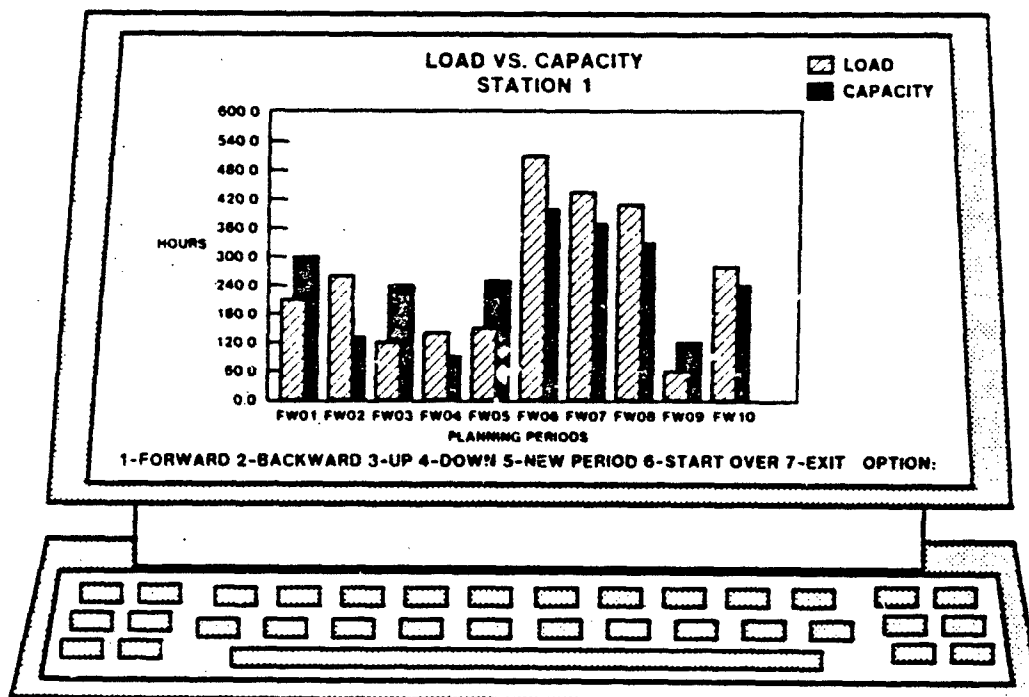


Figure 3-37. Bar Chart Display for Load vs Capacity

then proceeds to build queues of work load based on the assumption that a job is ready to be moved and queued for the next operation when complete on the current operation. Simulated queue times are thereby determined that can then be used in adjusting queue time assumptions for short-term loading and balancing.

The simulation also indicates underutilized machines and bottleneck machines. Such data can then be used by the production planner to modify selected loading rules or to make recommendations for increased or decreased capacity. A block diagram illustrating information interfaces and primary software modules for the simulation is included in Figure 3-38.

The simulation is performed by software referred to as the Schedule Evaluator AM (application model). Feedback in the form of hard-copy reports and interactive displays is provided by software referred to as the Heuristic Parameter Analysis AM.

The User's Manual that describes the Schedule Evaluator and Heuristic Parameter analysis is available in the ICAM Library referenced UM820540031.

Factory Loading Detailed Design Techniques

Several innovative techniques and concepts were incorporated into the detailed design of PP&CS Factory Loading software in support of several of the above functions. Specific techniques include:

- Multi-Tasking
- Automatic Restart in the Event of Deadlock
- Interactive Restart in the Event of System Failure (e.g., Power Outage, Disk Head Crash)
- Slack Time Sliding

Each of these techniques as incorporated within the design of PP&CS Factory Loading software is briefly described as follows:

13. Multi-tasking

Multi-tasking involves the execution of multiple concurrent tasks (implemented as "detached processes" under the VAX/VMS operating system) in an attempt to reduce the substantial amount of turnaround time required by Factory Loading background functions. Depending on the specific factory environment within which PP&CS is installed, it is possible that several of the previously described Factory Loading functions (namely LTL, LTB, STL, and STB) could be called upon to process large amounts of load information. 100,000 production requirements associated with 800,000 operations does not represent an unusual

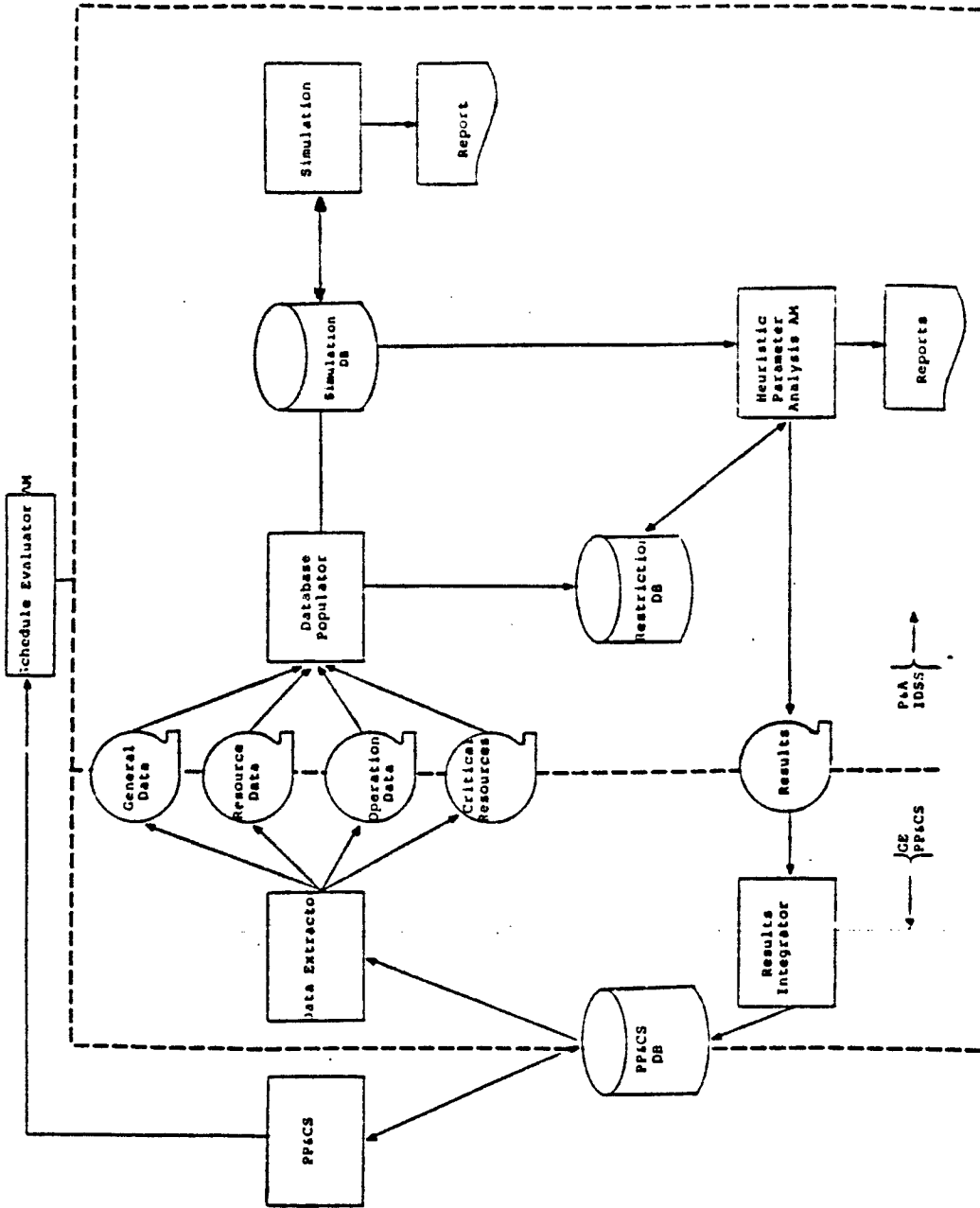


Figure 3-38. Relationship Between PP&CS and IDSS

volume of information to be processed for a six month time horizon in certain aerospace manufacturing environments. Multi-tasking is a technique for reducing the amount of time required to process large volumes of information.

Activities 3 and 5 illustrated in the data flow diagram for LTL (Figure 3-31) and the Perform Attempts activity for the LTB data flow diagrams (Figure 3-32) are examples of activities that can be multi-tasked.

14. Automatic Restart in the Event of Deadlock

The design of the LTL, LTB and STL Factory Loading functions also features the ability to periodically store "checkpoint" information which is integrated within the PP&CS data base. These functions are capable of detecting the event of a deadlock condition and, using checkpoint information, are designed to automatically restart from the last database "cleanpoint." This technique enables the function to continue with minimal loss of processing.

After detecting a deadlock condition, the PP&CS software will rollback (i.e., undo) modifications and locks that have been applied to the PP&CS data base since the last database cleanpoint (thereby resolving the deadlock condition) and will then restart the function.

15. Interactive Restart in the Event of System Failure (e.g., Power Outage, Disk Head Crash)

In the event of major system catastrophes, several Factory Loading functions have been designed to be interactively restarted without the need to perform substantial amounts of reprocessing. Examples of circumstances under which it is desirable to interactively restart Factory Loading functions include power failures and hardware failures such as disk head crashes. In all cases, the interactive restart feature uses the same checkpoint information used by the previously described automatic restart feature.

Note that in the event of the loss of a secondary storage device, it may be necessary to use "after images" stored within a "journal file" maintained by the data base management system (VAX 11 DBMS) to reconstruct (i.e., rollforward) the data base before interactively restarting the specific Factory Loading functions that were executing at the time of the failure.

16. Slack Time Sliding

The design of LTB and STB incorporates a novel technique referred to as "slack time sliding" used for the purpose of moving planned work (i.e., "load units") from overloaded to underloaded periods. This technique begins with the determination of total slack time available for each production requirement eligible for either the short-term or long-term loading process. Total slack time is calculated by subtracting the total manufacturing lead time (in terms of move time, queue time, and effective load hours for each operation of a part to be produced) from the total span time (due date minus release date as determined by MRP). The total slack time is divided up and allocated to each of the operations within a production requirement. Operations are then grouped into "load units" consisting of move time, queue time, effective load hours, and slack time as illustrated in Figure 3-39.

Software modules for LTB and STB were designed to take advantage of slack time associated with each load unit for the purpose of moving a load unit from its current overloaded planning period to either an earlier or later period. In addition, more sophisticated "look ahead" and "look back" algorithms were also developed to take advantage of slack time allocated to one or more load units following or preceding the current load unit under consideration.

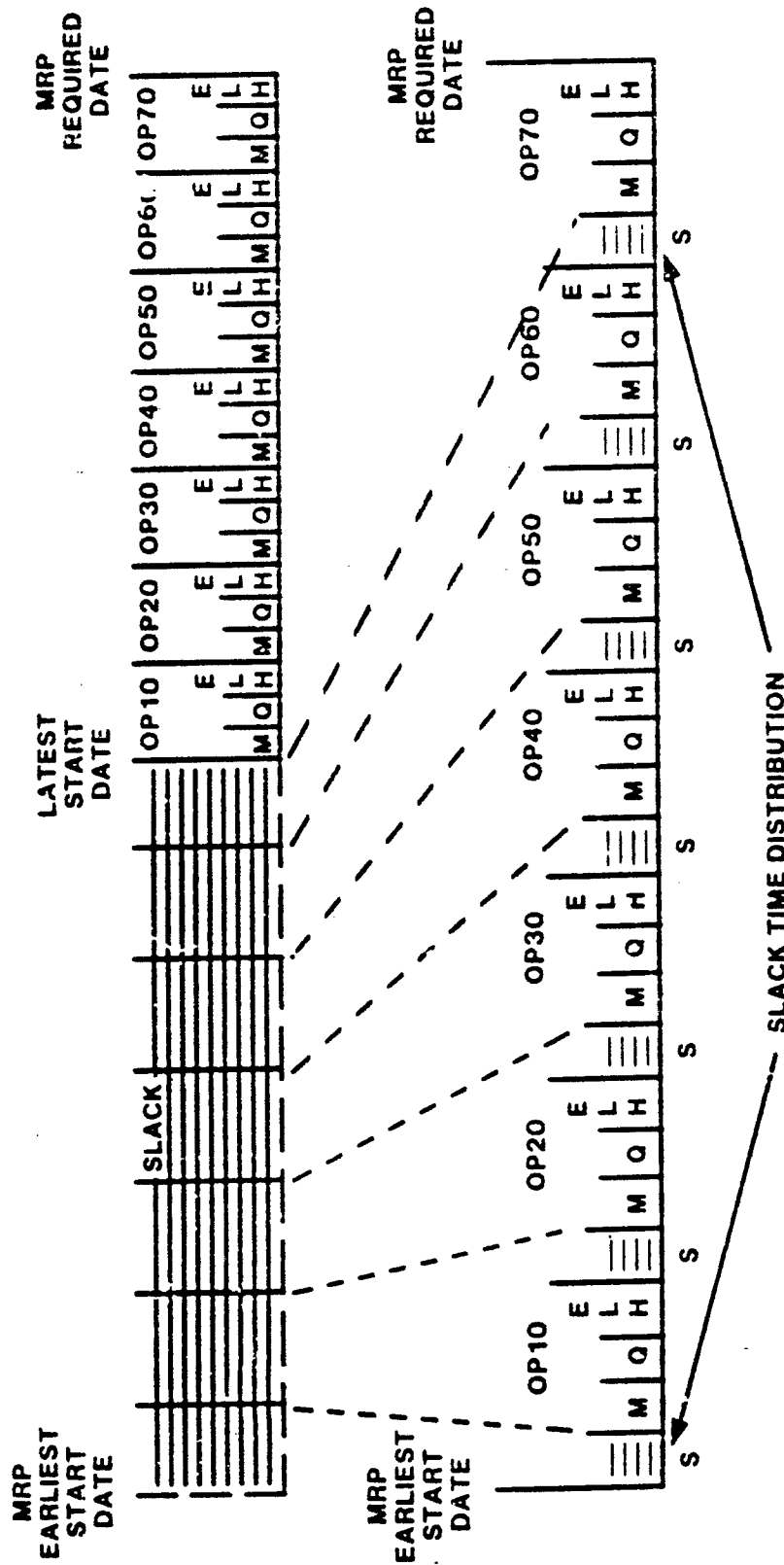


Figure 3-39. Production Requirement

To the best of our knowledge, slack time sliding and the techniques of generic "look ahead" and "look back" have never before been attempted in commercial Capacity Requirements Planning (CRP) packages. More detailed information regarding slack time sliding techniques is presented in the product specification for the Perform Factory Loading function (PS 550152061).

3.5.3.2 Record and Provide Production Information (PS550154081)

Accomplishments

A number of transactions were designed in support of the Record and Provide Production Information function of PP&CS. Specifically, detailed design documentation for the following transactions was developed.

1. Define Factory Levels

Before executing any of the previously described Factory Loading functions, it is first necessary to define the factory environment or organization at which PP&CS is to be installed. The first step in this process is to define the factory environment in terms of control levels, a function provided by the DEFINE FACTORY LEVELS transaction.

Specifically, this transaction enables the planner to define the names of levels and the total number of levels (up to a maximum of 10) for the manufacturing environment.

Figure 3-40 illustrates the ICAM Factory Hierarchy, a five level control structure composed of factory, center, cell, station and process levels. This transaction provides PP&CS with the flexibility required to accommodate the control structure of virtually any factory environment.

2. Define Factory Resource

After defining the levels, it is necessary to define the actual resources within the factory environment. A resource can be either a logical or physical resource. That is, specific machines or processes are physical resources and appear at the lowest level in the factory hierarchy. Capacity planning also involves logical resources, e.g., groups of machines, work centers, entire departments, etc., appearing at intermediate and higher levels in the factory hierarchy.

3. Delete Factory Resource

This transaction enables the planner to remove from the PP&CS data base previously defined resources.

4. Display Factory Hierarchy

This transaction enables the planner to interactively display, as an indented list, the defined factory hierarchy.

5. Define Machine Type

This transaction enables the planner to group specific machines or processes into machine types. Typical examples of machine types include DRILLS, MILLS, NC-LATHES, 6FT-SHEARS, etc. This step is required since PP&CS LTL software loads work to machine types within specific resources (i.e., "resource machine types") and because STL software associates work with specific machines within a machine type called out by the process planning information stored within the PP&CS data base.

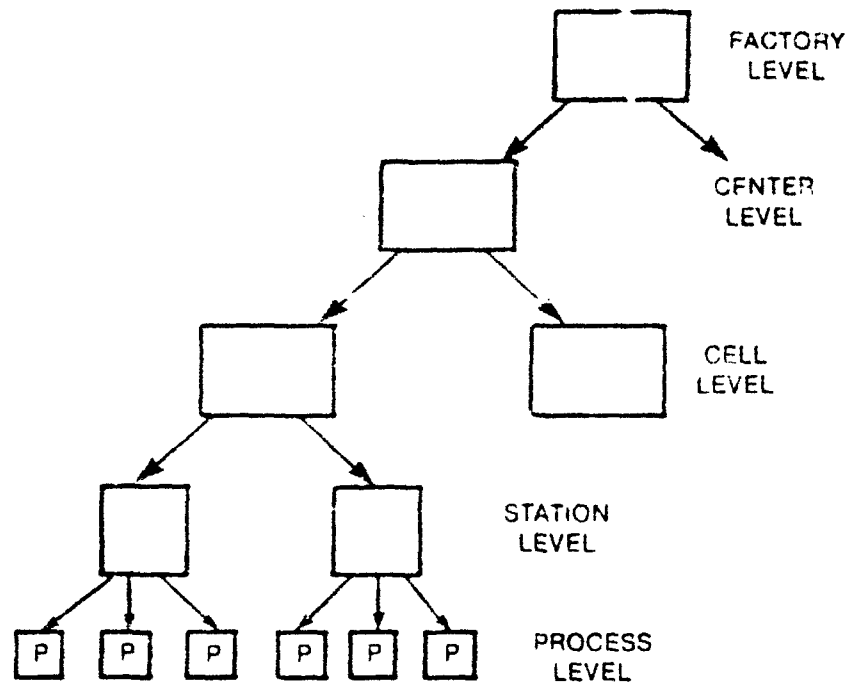


Figure 3-40. The ICAM Factory Hierarchy

6. Delete Machine Type Information

This transaction enables the planner to delete from the PP&CS data base previously defined machine type information.

7. Define Move Time Information

Backward and forward loading techniques employed within both long-term and short-term loading/balancing software take into consideration the time required to move a job from its current machine to the machine or process at which the next operation is to be performed. These planned move times must be established within the PP&CS data base and are accounted for during the process of offsetting work from its required date (backward loading) or from its start date (forward loading). This transaction enables the planner to interactively define planned move times.

8. Maintain Shop Calendar Parameters

Shop calendar information for the target manufacturing environment must also be defined prior to the invocation of long-term or short-term capacity planning software. This transaction enables the planner to define shop calendar parameters that will be used to construct the actual shop calendar within the PP&CS data base.

Specifically, this transaction enables the user to define a fiscal week to month breakdown, the beginning day of the fiscal week, an upper limit for manufacturing days (M-days), and shutdown days for which no M-days are assigned. The flexibility provided by this transaction enables PP&CS to accommodate shop calendars in use in many manufacturing environments without the need for special tailoring of the software.

9. Maintain Shop Calendar

After defining shop calendar parameters specific to the user's factory, it is then necessary to build the actual calendar within the PP&CS data base, a function provided by the MAINTAIN SHOP CALENDAR transaction. In particular, this transaction creates planning period records for calendar days, fiscal weeks, fiscal months, fiscal quarters, and fiscal years, and also associates M-days to calendar days. Such information is required by both long-term and short-term capacity planning software.

10. Display Shop Calendar Information

This transaction enables the planner to display shop calendar information constructed in accordance with the two previously described transactions. Figure 3-41 illustrates the format of this display.

11. Adjust Factory Load Parameters

Several additional parameters must also be defined prior to the execution of long-term or short-term capacity planning software. Among these are queue times, validation limits, compression factors, effectiveness rates, etc. The ADJUST FACTORY LOAD PARAMETERS transaction enables the user to define such parameters, each of which is described in detail in the product specification for Record and Provide Production Information function (PS 550152081).

3.5.3.3 Release Production Requirements (PS550153071)

Accomplishments

A number of transactions were designed in support of the Release Production Requirements function of PP&CS. Specifically, detailed design documentation for the following transactions was developed.

1. Set Release Parameters

This function enables a planner to set several release parameters that must be established prior to the actual release of work to the shop floor. Specific examples of release parameters include upper and lower limits of released work load for specific resources, in-work-date release intervals, and flags indicating whether or not work is to be automatically released to certain resources.

2. Assign Production Requirements

This function is designed to accept as input the schedule of production requirements established by previously described PP&CS STR software and to logically associate the schedule with specific resources to which the scheduled work will ultimately be released.

3. Estimate Release Dates

This function results in a determination of expected release dates for production requirements associated with a resource as a result of the ASSIGN PRODUCTION REQUIREMENTS function.

4. Display Release Schedule

This function enables the user to display the release schedule established via the ESTIMATE RELEASE DATES transaction. The release schedule is designed to be displayed either on the user's terminal or optionally as a hard-copy report.

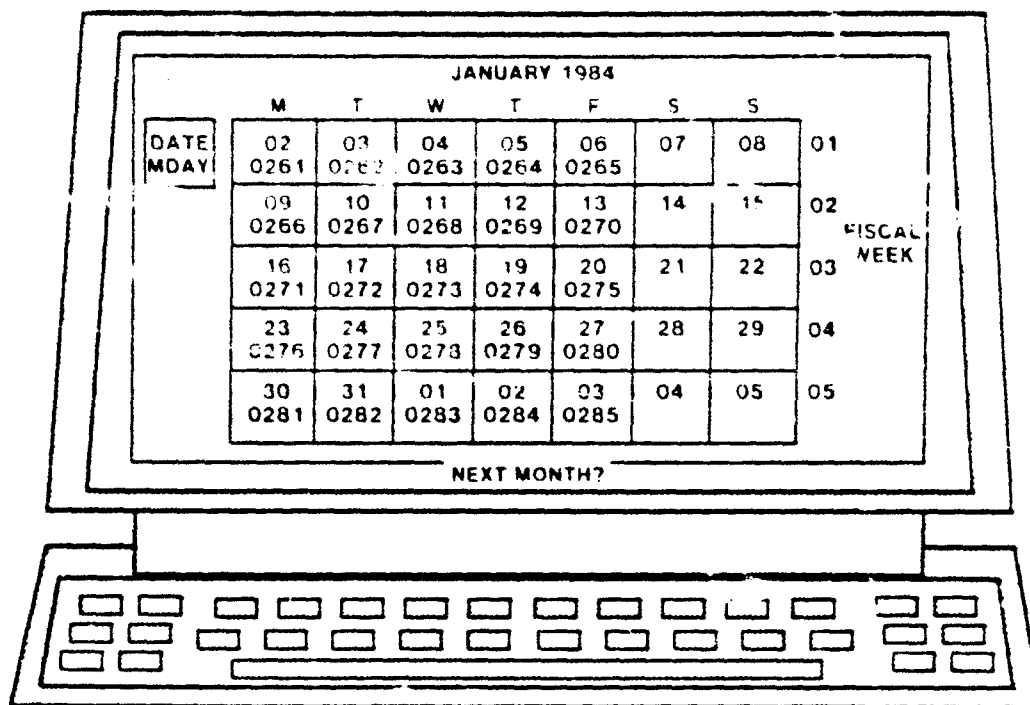


Figure 3-41. Format for Displaying Shop Calendar Information

5. Identify Quantity Adjustments

This function generates a report identifying quantity adjustments suggested for production requirements to be released for resources selected by the user. This transaction was originally included within the PP&CS design as a utility for suggesting quantity adjustments in the event that MRP software is not used at the manufacturing site at which PP&CS software is installed.

6. Adjust Production Requirements

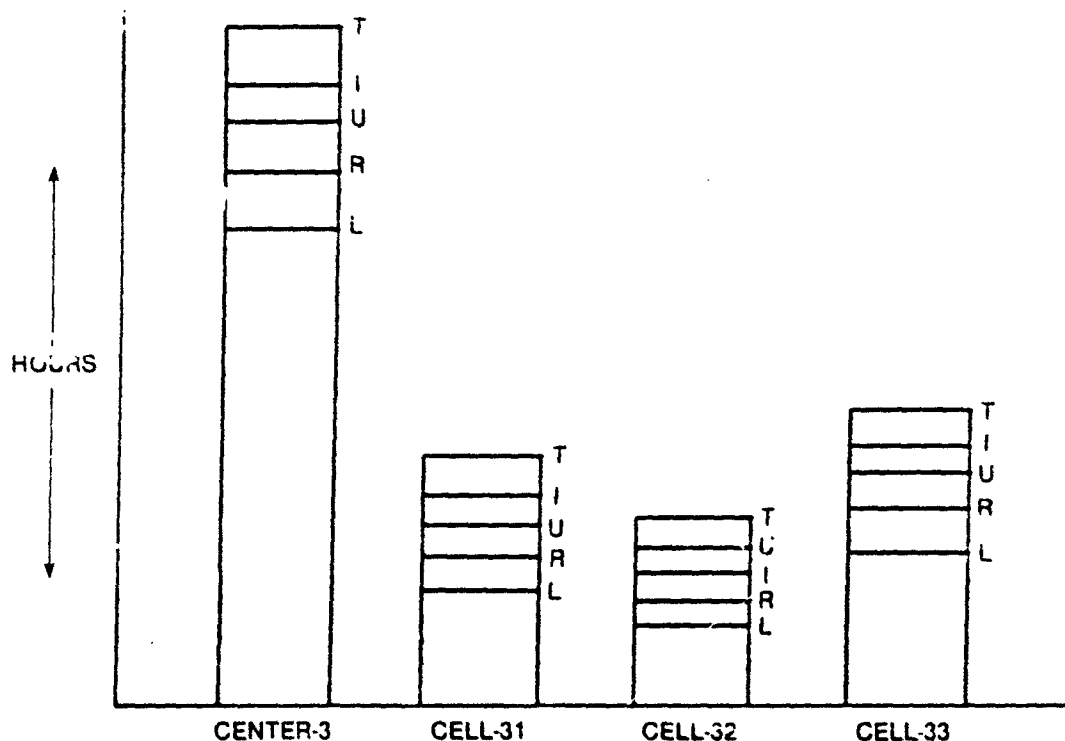
As a complement to the IDENTIFY QUANTITY ADJUSTMENTS transaction, this function enables the user to interactively modify quantities of parts identified on production requirements about to be released to the shop floor.

7. Display Load Status

This function displays current load information for all resources defined within the factory hierarchy. The display is presented both graphically and as a conventional text display.

8. Select Resources for Release

This function enables the user to select the resources to which production requirements are to be released and to specify the amount of work in hours to be released. (Illustrated in Figure 3-42)



U = RELEASED LOAD UPPER LIMIT
 L = RELEASED LOAD LOWER LIMIT
 R = ALREADY RELEASED
 I = IMPACT, THE AMOUNT OF WORK TO BE RELEASED
 T = TOTAL AMOUNT OF WORK FROM DETAIL SCHEDULE

Figure 3-42. Select Resources for Release

9. Analyze Release Impact

This function analyzes the workload about to be released to previously selected resources and determines the impact of the release on all resources. If, for example, it is determined that 1000 hours of work is to be released to a particular resource, this function provides the user with an understanding of how that 1000 hours will be distributed among lower-level resources. It is therefore possible to gain an understanding of potential short-term bottlenecks or underloaded situations. The need for overtime, reassignment, farmout, or expediting can therefore be more accurately predicted. Note that the output of this function is displayed via the invocation of the previously described DISPLAY LOAD STATUS function.

10. Release Production Requirements for Interactively Selected Resources

This function enables the user to release production requirements to resources defined within the factory hierarchy. Specific resources to which production requirements are to be released are selected via the SELECT RESOURCES FOR RELEASE function.

11. Start Automatic Release

This function enables the user to initiate the automatic release of work to resources that were previously identified as eligible for automatic release. Eligibility for automatic release is granted to a resource as a result of executing the RELEASE PARAMETERS function.

12. Stop Automatic Release

This function enables the user to terminate the automatic release of work to resources that were previously identified as eligible for automatic release. The automatic release mechanism is activated via the START AUTOMATIC RELEASE function.

3.5.3.4 Perform Resultant Processing (PS550152091)

Accomplishments

Detailed design documentation for three major resultant processing functions was completed during this phase of the project. These functions are:

1. Validity Check Feedback Information

This function is responsible for validating production information collected from the shop floor. Specifically, validation consists of:

- Checking actual performance information (e.g., actual run time, actual setup time, scrap counts, etc.) for identifying substantial deviations from standards
- Detection of missing values

This function is designed to accept as input performance information stored within the PP&CS data base by an appropriate shop floor control system. The output of this function is a report, illustrated in Figure 3-43, that identifies the deviations and missing values.

2. Update Historical Performance

This function is responsible for updating historical performance information. Examples of historical data maintained within the PP&CS data base include:

- ROUTING OPERATION HISTORY
- ROUTING OPERATION HISTORICAL SAMPLES
- MOVE TIME HISTORY
- MOVE TIME SAMPLES
- RESOURCE MACHINE TYPE HISTORY
- PART HISTORY
- PART HISTORY SAMPLES

This function maintains parameters indicating the maximum number of samples that can be stored for each category of historical information, thereby enabling the manufacturing site to manage the growth and proliferation of historical information within the PP&CS data base. The oldest samples are deleted from the data base when upper limits are reached.

Note that the VALIDITY CHECK FEEDBACK INFORMATION and UPDATE HISTORICAL PERFORMANCE functions were integrated within the design of a single transaction.

VALIDITY CHECK RESULTS			
DATE: YY/MM/YY			
<u>MISSING VALUES</u>			
ORD aaaa	OPER aaaa	PART aaaa	WORK CTR aaaa
<u>MISSING VALUES</u>		<u>SUBSTITUTED STD</u>	
VALUE		XXXX	
VALUE		XXXX	
ORD aaaa	OPER aaaa	PART aaaa	WORK CRT aaaa
<u>MISSING VALUES</u>		<u>SUBSTITUTED STD</u>	
VALUE		nnnn	
<u>VALIDATION VIOLATIONS</u>			
ORD aaaa	OPER aaaa	PART aaaa	WORK CRT aaaa
<u>ACTUAL VALUE</u>	<u>STANDARD</u>	<u>LIMITS</u>	<u>SUBSTITUTED VALUE</u>
VALUE	VALUE	Fl: nn to nn	VALUE

Figure 3-43. Validity Check Results

3. Analyze Performance

This function is primarily responsible for retrieving historical performance samples for any of several variables stored within the PP&CS data base (after validation has been performed) and plotting associated scatter diagrams and trend lines. This function thereby enables the planner to determine whether significant trends are developing (e.g., determining whether or not learning curves are being overcome for new processes).

Specific types of data analyzed by this function include:

- Move Time Deviation
- Queue Time Deviation
- Setup Time Deviation
- Setup Loss Deviation
- Delivery Variance
- Slack Time
- Quantity Variance

- Operating Time Deviation
- Total Span Time

A sample display generated from this function is illustrated in Figure 3-44.

3.6 TASK 6. SUBTASK 1: DEVELOP "CONSTRUCT, INTEGRATE AND TEST" SUB-PLAN

3.6.1 Construct, Integrate, and Test Plan

Accomplishments

A provision for a test plan that included training, coding, testing, verification, and systems test was developed in Task 5, Subtask 3. In this task, the plan was reviewed for completeness and communicated to the software engineering team.

At this time the plan was finalized for the implementation and demonstration of the PP&CS prototype system. The computer selected for coding, testing, and implementation was the VAX 11/780 and the VAX 11 DBMS.

3.6.2 Task 6, Subtask 2: Construct, Code, and Verify IPS Subsystem Prototype

Accomplishments

This phase of the project resulted in the construction of approximately 2000 discrete software modules addressing all of the functions in Section 3.5.3 for the following PP&CS areas:

1. Perform Factory Loading
2. Record and Provide Production Information

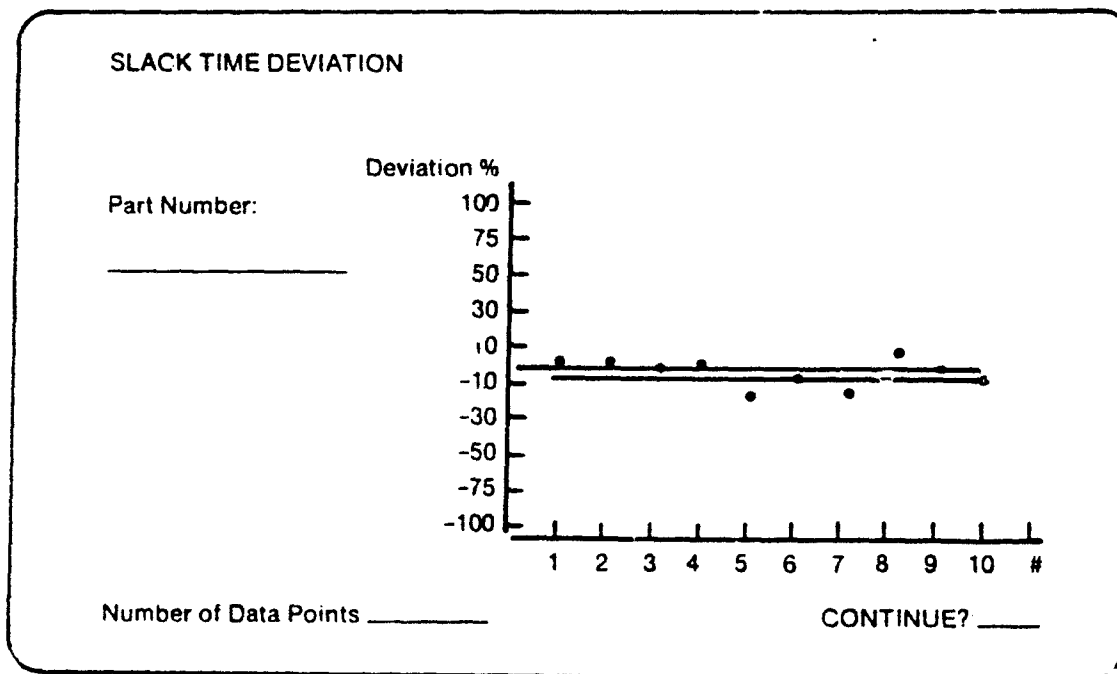


Figure 3-44. Slack Time Deviation

3. Perform Resultant Processing

In order to effectively carry out this phase of the effort, it was necessary to address a number of software implementation issues and problems. Specific concerns encountered during this phase are summarized as follows:

1. Choice of Computer System

It was originally contemplated that PP&CS be demonstrated as a subsystem executing under the control of the IISS test bed (ICAM project 6201). The initial implementation of the test bed, for which PP&CS was targeted, demonstrated data integration within a distributed heterogeneous computer network consisting of VAX 11/780, Honeywell Level 6, and IBM 3033 computer systems. Clearly, before PP&CS software could be constructed, it was first necessary to choose the test bed computer system on which PP&CS software would be implemented and demonstrated.

An analysis was performed for the purpose of selecting the target computer, specifically, the operating environments, i.e., operating system, compilers, available data base management systems, screen formatting/forms management software, etc. for each of the three above systems. Other non-technical issues, such as computer system popularity within the aerospace community, contract funding for computer system usage (i.e., connect time, disk usage, cpu usage), and available capacity were also considered in the final decision making process.

The final recommendation of the PP&CS development team was to proceed with the implementation of PP&CS on the VAX. Primary reasons in favor of this choice included:

- Richness of the operating environment (vendor supported CODASYL-compliant data base management and screen formatting software)
- Availability of development capacity on both IISS and General Electric-owned VAX systems
- VAX popularity within aerospace industry

2. Choice of Implementation Language

The language recommended for PP&CS implementation was the ANSI '74 COBOL standard. Primary reasons for this recommendation included:

- Vendor support of standard interface (CODASYL) for data base management
- Compliance with initial IISS test bed standards
- Maintainability and readability
- User preference as evidenced by an overwhelming number of computer-aided manufacturing systems implemented in COBOL

3. Choice of Data Base Management System

Having selected the VAX as the target implementation system, it was then necessary to explore alternative approaches for implementing the PP&CS data base. Three different data base management systems were considered:

- VAX 11 DBMS
- ORACLE

- The IISS Neutral Data Manipulation Language (NDML) and Common Data Model (CDM)

VAX 11 DBMS was selected. A primary reason for this selection centers around the issue of transportability. VAX11 DBMS is a CODASYL-compliant data base management system. The CODASYL approach to data base management is well-understood within the computer industry and is supported by many computer vendors as a standard. Integral feature of the COBOL compiler. ANSI '74 COBOL coupled with a CODASYL-compliant DBMS provides a relatively strong degree of transportability and enhances the probability of successful PP&CS radiation within the aerospace industry.

ORACLE, on the other hand, represents a newer technology in data base management (i.e., the relational approach). To the best knowledge of the PP&CS development team, no ORACLE customer had previously applied ORACLE to the problem of managing large volumes of tightly interrelated data for a software application as complicated as manufacturing capacity planning. The performance capabilities of ORACLE for the PP&CS application therefore could not be verified without extensive testing and prototyping.

The primary reason for not recommending the IISS NDML was the fact that its initial implementation within the IISS test bed was planned to support a "read only" capability. A local update capability for the NDML/CDM combination, which would have been required for PP&CS implementation, was targeted for a test bed software release scheduled beyond PP&CS schedule requirements.

4. Choice of Forms Management Software

Having selected the VAX as the target implementation system, it was also necessary to explore alternative screen formatting packages for implementing the PP&CS user interface. Two screen formatting packages were considered:

- FMS (Form Management System), a DEC standard product, and
- The IISS User Interface (UI), screen formatting and virtual terminal interface software developed under the 6201M effort.

FMS was selected primarily for the following reasons:

The timing of the development releases for IISS software did not coincide with the scheduled needs of the construct, integrate and test of PP&CS.

- *FMS Reliability:* FMS is vendor-supported. It exists, has been proven to be reliable, and is well-accepted in user communities.
- *Schedule Imbalance:* The product calendar for IISS User Interface was not in synchrony with PP&CS schedule requirements. PP&CS implementation commenced prior to completion of the initial release of the Test Bed UI.

5. Transaction Processing

The issue of whether or not to use a transaction processor to control the invocation and execution of PP&CS application programs was also addressed during this phase. It was decided that the PP&CS implementation did not require use of a transaction processor.

The principal reasoning underlying this conclusion was that most critical PP&CS application programs are designed to be invoked interactively by a PP&CS user but will then execute in "background mode" for a duration of perhaps several hours. LTL, LTB, and STL are examples of this mode of execution.

Transaction processors, however, have traditionally been used for applications where many users need to execute simple application programs requiring fast response time, unusual amounts of terminal I/O and/or data base I/O, (e.g., airline reservations, banking, shop floor control, etc.). For such applications, a transaction processor is sometimes used, serving as a message manager for optimizing and controlling terminal I/O.

Access to PP&CS functions, on the other hand, will normally be restricted to only a few factory personnel (e.g., a factory load planner and a person responsible for release to the shop floor). Fast response for important PP&CS applications is neither required nor possible with contemporary computer technology. Very little terminal I/O is also required by PP&CS application programs. Use of a transaction processor for PP&CS was therefore not regarded as essential.

6. Considerations When Executing "Background" Jobs

As previously described, several PP&CS factory loading functions run as background jobs capable of being executed in a "multi-tasked" mode of operation. As a result of this approach, several related technical issues needed to be addressed during this phase of the project. Among them were the determination of VAX/VMS mechanisms for:

- Controlling the creation and execution of background jobs
- Sending completion/error messages from a background job to the initiating user
- Controlling user access to currently executing background jobs.

Solutions for each of these issues were devised and are appropriately documented in the as-built product specification for Factory Loading.

In addition to the above issues, a number of more detailed implementation issues were also addressed during this phase of the effort. Discussion of these issues is included in appropriate product specifications referenced in paragraph 3.5.3.

3.6.3 Task 6, Subtask 3: Integrate, Test, and Validate IPS Subsystem Prototype

Accomplishments

This phase of the project resulted in the unit testing and integration testing for the following PP&CS functional areas:

1. Perform Factory Loading
2. Record and Provide Production Information
3. Perform Resultant Processing

Several noteworthy techniques, described as follows, were employed to more effectively carry out the software testing process:

1. Antibugging

A technique referred to as "antibugging" was incorporated within all source codes constructed for PP&CS application software. Yourdon, in his text "Techniques of Program Structure and Design" (Prentice-Hall 1975), defines antibugging as "the philosophy of writing programs in such a way as to make bugs less likely to occur, and when they do occur (which is inevitable), to make them more noticeable to the programmer and the user."

Accordingly, designers of each transaction were commissioned with the responsibility of ensuring that all PP&CS application software be suitably equipped with appropriate mechanisms for detecting exception conditions. All software was designed such that the detection of an exception condition is then followed by the display of an appropriate message indicating not only the nature of the exception condition but also the name of the software module executing at the time the exception condition was detected, and the circumstances under which the exception condition was generated.

2. Testing by Software Inspection

Software inspection procedures were also established to identify logic errors and violations of design/coding standards prior to the actual execution of individual transactions. Specifically, implementors were instructed to expend some "startup" time for reviewing detailed design documentation for the assigned transaction. Points of confusion, change proposals arising from constraints associated with the target operating environment, and an overall implementation approach were then mutually formulated by the chief programmer and the implementor.

After the resolution of any startup problems, the implementor then proceeded to interactively create screen formats and source modules. This step was then followed by compilation, which repeated until all syntactic problems were eliminated.

Cleanly compiled source modules were then submitted for inspection to the detailed designer, who was then responsible for ensuring that algorithms were accurately interpreted by the coder and that standards had been adhered to. This inspection process resulted in the identification and interception of a substantial number of errors, thereby reducing the amount of time that otherwise might have been expended for formal testing and debugging.

3. Transaction Testing

Satisfactory completion of the inspection step was then followed by both unit testing and transaction testing usually performed by the detailed designer. For straightforward transactions, test cases were informally identified and executed. Antibugging techniques, as previously described, were heavily relied upon for identification of software problems. For some transactions, test specifications identifying specific test cases, descriptions of tests, and test data were developed.

4. Integration Testing

Integration testing demonstrating proper coordination and interfacing among sequences of transactions was usually performed subsequent to the satisfactory completion of unit testing and transaction testing for each transaction included within the scope of a specific integration test. In some cases, however, it was necessary to perform integration tests in conjunction with unit testing and transaction testing.

Specifically, integration testing was performed according to the following steps:

1. Integration of STB with prototype configuration software:

STB was the first major PP&CS function developed. STB served as a vehicle for demonstrating PP&CS progress at the ICAM Industry Days conference in New Orleans in June 1983. This software was integrated with prototype software for initializing the data base with production requirements and miscellaneous information for defining the factory environment and factory loading parameters.

2. *Integration of Record and Provide transactions:*

Integration testing was then carried out for transactions identified within the Record and Provide Production Information function.

3. *Integration of PREPARE MRP INPUT transaction with Record and Provide transactions:*

Integration of the PREPARE MRP INPUT transaction with record and provide transactions actually commenced prior to completion of unit testing for the PREPARE MRP INPUT transaction. This was necessary because of the need to appropriately initialize the PP&CS data base via execution of Record and Provide transactions supporting the Factory Loading function.

4. *Integration of LTL with the DEFINE CAPACITY AND PREPARE MRP INPUT transactions:*

This integration step was performed in conjunction with LTL unit testing.

5. *Integration of LTL with LTB*

6. *Integration of LTL with STB*

7. *Integration of STL with STB*

8. *Integration of LTL/LTB with Transactions for Results Presentation*

9. *Integration of STL/STB with Transactions for Results Presentation*

10. *Integration of Resultant Processing Transactions*

3.6.4 Task 6, Subtask 4: Implement and Maintain IPS Subsystem Prototype

This phase of the project resulted in the development of user instruction information, software/data base maintenance information, operating procedures, and installation procedures for the following PP&CS functional areas:

1. Perform Factory Loading
2. Record and Provide Production Information
3. Perform Resultant Processing

A PP&CS user's manual (UM 550150300) was developed that includes the following information:

1. General Operating Procedures
2. Transaction Descriptions
3. User Instructions for Transaction Execution
4. Sample Screen Formats for Each Transaction
5. PP&CS Software Installation Procedures

PP&CS data base maintenance information was incorporated within a data base specification (DBS 550150000) developed in accordance with ICAM documentation standards.

Software maintenance information including structure trees (i.e., indented module lists), module descriptions, file descriptions, table descriptions, etc., for all PP&CS transactions was developed and incorporated within product specifications also developed in accordance with ICAM documentation standards.

PP&CS software was not installed at a specific manufacturing site as a result of this effort. The results of the PP&CS effort were demonstrated to industry representatives at an end-of-contract review meeting for Project Priority 5501.

3.7 TASK 7: PROJECT MANAGEMENT AND DATA

Accomplishment

This task provided the project management and data for overall program control. This activity consisted of project monitoring and reporting of General Electric performance in compliance with the Air Force contract requirements.

The monitoring of IPS subcontractor compliance with contract requirements was also accomplished in this task. The General Electric project manager provided project progress and results, as well as the required ICAM documentation and contract deliverables, to the Air Force, external contractors, and the public.

Section 4

REFERENCE MATERIAL

The following reference material is available in the ICAM library and is pertinent to the IPS project. A synopsis and overview of IPS technical work accomplished during the life cycle of Project Priority 5501 is contained in Section 2 of this final report.

4.1 PREVIOUS INTERIM REPORTS

<u>Document Number</u>	<u>Date</u>
MIS-81-016	31 December 1980
ITR 550150002U	31 March 1981
ITR 550150003U	30 June 1981
ITR 550150004U	30 September 1981
ITR 550150005U	31 October 1981
ITR 550150006U	31 March 1982
ITR 550150007U	30 June 1982
ITR 550150008U	30 September 1982
ITR 550150009U	31 December 1982
ITR 550150010U	31 March 1983
ITR 550150011U	30 June 1983
ITR 550150012U	30 September 1983
ITR 550150013U	31 December 1983

4.2 LIFE CYCLE DOCUMENTS

<u>Document Number</u>	<u>Description</u>	<u>Date</u>
	Scope Kit	15 January 1981
	Needs Analysis Document	3 March 1981
SED 550150000	System Environment Document	9 November 1981
SRD 550150000	System Requirement Document	9 November 1981
SAD 550150000	State-of-the-art Document	9 November 1981
SAR 550150000	State-of-the-art Review	16 October 1981
SS 550150000	System Specification	30 June 1982
SDS 550150000	System Design Specification	9 September 1982
DS 550152061	Development Specification	
	- Perform Factory Loading	17 December 1982
DS 550153071	Development Specification	
	- Release Production Requirements	15 December 1982
DS 550154081	Development Specification	
	- Record & Provide Production Information	17 December 1982
DS 550152091	Development Specification	
	- Perform Resultant Processing	15 December 1982
DS 550156111	Development Specification	
	- PP&CS Interface	15 December 1982
TP 550150001	Test Plan	15 December 1982
QAP 550150001	Quality Assurance Plan	3 February 1983

Document Number	Description	Date
DBS 550150000	Data Base Specification	1 May 1984
PS 550152061	Product Specification - Perform Factory Loading	1 May 1984
PS 550153071	Product Specification - Release Production Requirements	1 May 1984
PS 550154081	Product Specification - Record & Provide Production Information	1 May 1984
PS 550152091	Product Specification - Perform Resultant Processing	1 May 1984
UM 550150000	Users Manual	1 May 1984

4.3 VENDOR-SUPPLIED DOCUMENTATION

A detailed understanding of the vendor-supplied support software, upon which PP&CS was built, can be obtained from the following manuals available from Digital Equipment Corporation:

<u>DEC Publication Number</u>	<u>Manual Title</u>
AA-C985A-TE	VAX-11 Cobol-74 Language Reference Manual
AA-C986A-TE	VAX-11 Cobol-74 Users Guide
AA-L629A-TE	VAX-11 Common Data Dictionary Utilities Manual
AA-L630A-TE and AD-L360A-T1	VAX-11 Common Data Dictionary Installation Guide
AA-J966A-TE	VAX-11 DBMS Data Base Administration Manual
AA-J961A-TE	VAX-11 DBMS DDL Reference Manual
AA-J960A-TE	VAX-11 DBMS DML User's Guide
AA-J964A-TE	VAX-11 DBMS Summary Description
AA-J962A-TE	VAX-11 DBMS Utilities Reference Manual
AA-J965A-TE	VAX-11 DBMS Installation Guide and Release Notes
AA-J260A-TE	VAX-11 FMS Software Reference Manual

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